ASPECTS OF SCIENCE

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PREFACE

The papers which make up this volume have been selected because, although they deal with different aspects of various scientific ideas, yet they do illustrate, more or less, one point of view. That point of view may be described, perhaps as aesthetic, but rather better as humanistic. Scientific ideas have a history; they arose to satisfy certain human needs; to see them in their context is to see them as part of the general intellectual and emotional life of man. What they exist to do they do better than does anything else, and the needs they satisfy are not peculiar to scientific specialists. These papers try to show one or two of the many reasons why, for people who are not specialists as well as for those who are, science may be interesting.

J. W. N. SULLIVAN.

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THE INTEREST OF SCIENCE

I

The conception of science as a body of thought embracing the whole of our rational convictions about reality has hardly yet been generally reached. Man is still so far from being a rational animal that the application of rational methods of inquiry to all branches of his experience is still instinctively resisted—as if reason were an alien and hostile intruder. Beliefs which are held with passion, being the expression of instinctive preferences, are felt not to belong to the "sphere" of science. On all questions where his passions are strongly engaged, man prizes certitude and fears knowledge. Dispassionate inquiry is welcomed only when the result is indifferent. Nearly every great scientific generalisation has incurred the *odium theologicum* —which is not the exclusive possession of theologians—from the Copernican hypothesis to the theory of herd instinct. That science, although continually wounding men, should nevertheless have progressed, is evidence that it serves impulses deeply rooted in man's nature. The great scientific

innovator, like the great altruist, is treated with ignominy by the society whose deepest instincts he lives to serve.

Science, the child of irrational impulse, has inherited something of the parental character. Its history reveals it as purblind and fumbling, with no clear vision of its aim, no premonition of its imperial state. Unlike philosophy, it did not aspire to universal dominion. It was content to investigate the particular instance, and did not reject a certain incoherence in explanation rather than accept a generalisation which did not spring from its own ground. It refused foreign assistance, but kept its independence. That scientific men did not always understand that science must, from its nature, be autonomous, is evident from the history of every particular science. Even as late as Descartes it was considered quite natural to deduce phenomena from metaphysical principles; and an admixture of mythical elements is not entirely absent from some branches of science, even at the present day. Science has not yet reached full consciousness of its proper ground and aims.

The values served by science, in terms of which its claim to consideration is to be judged, have become more numerous as science has developed. The earliest scientific researches were concerned wholly with the particular event, with, at most, the vaguest inkling of large perspectives. The savage who discovers that the branch lying partly

in the stream is not really bent, is prompted by the same localised and detached curiosity which led to most of the early scientific discoveries. Interest in the oddity of an event is undoubtedly the root of scientific observations. The more closely the events concern us, the more pregnant they may be with possible pleasure or pain, the greater the degree of abstraction necessary to see them in their relations. Human beings remain miracles to us long after we have learned to predict the motion of a planet. Psychology is the latest of the sciences, not so much because of the intrinsic difficulty of its subject-matter as because our interest in the subject-matter is so vehement that it is almost impossible to be indifferent to the results. An intelligent fish would probably have found most of the painfully won results of human psychology fairly obvious.

From the accumulation of facts and the attempt to see them in relation springs the scientific theory. With the construction of theories science enters on a new phase in its development, and serves a different set of human values. Its facts, the products of local curiosities, now take on an order, and serve the desire for comprehension. The apparently dissimilar becomes related ; law supervenes on chaos. The desire for knowledge becomes transformed into the desire for *significant* knowledge—significant primarily for contemplation, and secondarily for practice. It is the scientific theory alone that gives to science its true being and makes

it worthy of a deep concern. The desire for comprehension is deeply rooted in human nature. Religious myths and philosophical systems arose in obedience to this impulse. Science also exists to satisfy this craving, and the terms on which it does so are altogether to its advantage. The fact that it is an extension of common knowledge, and infers nothing that cannot be verified, differentiates it from myth, and is the secret of the grave and serious satisfaction it affords. Those accustomed to this homely, invigorating atmosphere find the rarer air of much traditional philosophy quite insupportable. A certain indifference to other methods of describing reality becomes more evident as the years advance and the domain of science becomes more and more extended. Peaceful penetration takes the place of open warfare, and in face of rival systems men of science feel less inclined to disprove what they feel more at liberty to ignore.

Science still falls far short of affording complete comprehension or of providing so finished a picture of reality that we feel no need of other speculations. The different sciences do not yet conspire to form one single coherent body of truth. The interstices between them are still sufficiently large to admit foreign interpretations. But the impulse to comprehension, which created science, will be justified by it: we may have so much faith. Even that moiety of mankind who care for little beyond pure immediacy will find that science alone can give

them much of what they desire. Scientific theories possess a value even to those who are strangers to the pleasures of contemplation, for science has powerful reactions in the world of practice. To those who have lost their birthright it can offer a mess of pottage.

Besides serving curiosity, comprehension and practice, science offers richly satisfying objects to the æsthetic impulse. The language of æsthetics is not far to seek in the writings of men of science, and were it not that the word arouses such a proprietary fury, we should agree, reviewing their motives and the kind of their satisfactions, to call them artists. The matter of the highest art, like that of true science, is reality, and the measure in which science falls short as art is the measure in which it is incomplete as science. All good philosophy, art or science partakes of the nature of the other two. When these three are regarded as one, each will have reached its apotheosis.

II

It is unfortunately true that as a science advances it grows more complex. Not only does its language depart more and more from ordinary speech by the accumulation of technical terms, but the terms in current use at any time are defined in terms of others which are defined in terms of others—something after the manner of the description of the

house that Jack built. The most obvious case of this Chinese box kind of language is, of course, that of mathematics. A mathematical theorem occupying one line of type might very well occupy a volume if written out in ordinary prose in which no terms were used which were not common property. For this reason modern mathematical discoveries, except in very special instances, cannot be made intelligible except to mathematicians. To learn the language of a highly developed science like mathematics takes about as long as to learn Chinese, but the task of translation into English is very much harder. For this reason mathematicians cannot hope for intelligent popular recognition; they must be content to be regarded either as vaguely impressive figures or else as mild lunatics busied with incomprehensible and probably trifling abstractions. Compared with writers, musicians or painters, they are, for social purposes, mental outlaws. It is apparent, however, that mathematics was not always so remote. It was possible for Voltaire to take an interest which was, at any rate, enthusiastic, in the work of Newton. This was doubtless due, in some degree, to the obviously dramatic quality of Newton's discoveries, but it was also due to the fact that his discoveries could be expressed in comparatively simple language. Again, physics and chemistry at that time, and for some years later, were not only intelligible to men without special training, but such men could actually make valuable discoveries

in these sciences. As these sciences progressed their language became more and more forbidding and their fundamental notions more and more abstract. Men without special training, but with scientific curiosity, turned their attention to the biological sciences. They collected birds' eggs and butterflies; they bought microscopes and wrote little papers on the sea-shells they discovered in a morning's walk. But biology has now developed a technical language, and the days of the untrained observer are almost over. The one science which is still, to some extent, accessible to these amiable people is psychology. It is growing more technical, it is true, but the majority of the books dealing with psychology may still be read almost as easily as a treatise on the history of the Balkans. And the "psychological" novelist can still regard himself as being, from one point of view, a scientific man. Psycho-analysis is, as yet, a favourite subject of discussion in advanced drawing-rooms where discussions of the principle of relativity are comparatively rare.

The divorce between science and the general intellectual world is unfortunate, but inevitable. It is unfortunate both for the scientific man and for the general *intelligentsia*. The scientific man, mentally companionless except for the little circle of his immediate co-workers, becomes less complete as a human being; he fails as a humanist. He too often accepts his outlawed position and turns his special interests into his exclusive interests,

as if, through some inverted generosity, he refused to take where he could not give. He may grow to ignore the other intellectual activities of his time, as Darwin, to his distress, found he had grown to ignore poetry, or he may actually become intolerant of such activities and so add contempt to the ignorance with which his preoccupations are regarded by the outside world. For the outside world, also, this divorce is unfortunate. For science, in its own way, satisfies just the same impulses as do other intellectual interests, and some of them it satisfies more completely and in a richer way. A great waste of mental energy and much inconclusive discussion would be avoided were certain scientific results more generally known, and, more particularly, were the advantages of the scientific method more widely recognised and the method itself more extensively practised. An air of superiority is often noticed in the references of scientific men to certain current discussions. It is a fault of manner, but one difficult to avoid. "Inside" information usually has this effect on the possessor, and when it is information that cannot be shared the attitude is apt to become chronic. Both sides, then, are the poorer for their lack of intercourse. But this state of affairs seems to be inevitable. The claims of the Latin and Greek literatures to attention, whether they are justified or not, have led to the study of these languages being imposed on perhaps the majority of the people in this country who are predomin-

antly interested in intellectual affairs. It is a training which consumes several years: is a training in the sciences to be added? This is manifestly impossible. Even if our whole educational system were radically altered, only those sciences, such as biology and psychology, which may be understood with comparatively little training, could ever become objects of common knowledge. But sciences where, in addition to a severe and prolonged discipline, special aptitude is necessary, must always be the property of the few. As, every year, all the sciences grow more complex, so the difficulty of obtaining an adequate knowledge of them increases. A dead language may be learnt once for all, but the language of a science must be learnt afresh every few years. The popular article of Huxley's day, the link between the man of science and the general public, is now the link between the more and less advanced students of the same science. A so-called "popular" account of Relativity Theory, for instance, is like an annotated edition of Pindar; a very fair knowledge of the language is assumed beforehand. It might be thought that the process of reduction, as it were, could be continued, until finally an account was prepared where no technical terms were used. But such an account would be, at best, like a translation of Greek poetry; the essential quality would be gone. Such translations have, of course, their uses, but the attraction of science for the scientific man, like the attrac-

tion of a poem for the poet, is not to be communicated in this way. In art the separation of matter and form is not really possible, and the same is true of the sciences.

III

In their apologias, which have now become so common, men of science never weary of pointing out that it is the method of science which is really worthy of adoption by philosophers and that the results of science are merely provisional. The philosopher who bases his system upon the results reached at any given time by any given science has ensured the ultimate downfall of his system. He is sometimes told that the adoption of scientific methods, on the other hand, will enable him to make sure progress. At first sight there seems to be a contradiction here, for if the scientific method is infallible why are the results reached by it provisional? To judge from the history of science, the scientific method is excellent as a means of obtaining plausible conclusions which are always wrong, but hardly as a means of reaching the truth. The contradiction is only apparent, however, for it will be found that there is a part of every discarded hypothesis which is incorporated in the new theory. The discarded hypothesis proves to have been too general; the scientific man made a mistake of the same kind as the philosopher who uses the hypothesis as the basis of

a general system. It is now known, for instance, that Newton's theory of gravitation is very probably not exactly true; in most cases, however, it remains very nearly true, and there are large regions of dynamical astronomy which are unaffected by the alteration. The Newtonian laws of motion, again, are not sufficient to describe the motion of bodies moving with very large velocities, but they are very nearly true for all ordinary velocities. That the theories which have taken the place of those abandoned are exactly true is very improbable; they are, however, nearer the truth. We may say, therefore, that while the scientific method may, quite possibly, never enable us to reach the exact truth, successive applications of it enable us to approximate nearer and nearer to the exact truth. In this lies its chief difference from the methods usually adopted in philosophy, which aim at obtaining, at one blow, theories which shall never need revision. It is for this reason that philosophy does not progress.

In what, then, does the scientific method consist? It would be difficult to give a precise definition; it has, however, two main characteristics, the choice of facts and the treatment of facts. It does not seem to be generally recognised that scientific men do choose their facts; there are many people who suppose that all facts are of equal interest to scientific men, and that information respecting the number of nightingales heard

in Hertfordshire during a certain month, for instance, is a contribution to scientific knowledge. It should be obvious, however, that a mere random collection of facts is very unlikely to aid either practice or theory. The aim of science is not to form catalogues, but to form theories describing phenomena, and to this end some facts are pertinent and a very great number are not. All men, faced with a problem of any kind, choose such facts for examination as they consider relevant. Sherlock Holmes often bewildered Watson by pondering over facts that Watson considered irrelevant, but Watson's surprise was a proof that even he had a standard of relevance. The history of any science shows that the facts first chosen were those most likely to be repeated. Such facts obviously lead to statements which have a greater or less degree of generality. That an unsupported stone falls to the ground is a fact of this kind. The facts chosen by the man of science are those that permit generalisation. For this reason they usually differ entirely from the facts of interest to historians. After selecting, in accordance with this principle, the facts which are to be examined, the next step consists in establishing relations between sets of these facts. The precise expression of these relations is called a law of nature, to use a somewhat old-fashioned terminology. If now all the relations between certain sets of facts can be expressed in one general statement, that general statement is called a scientific theory. The

ultimate aim of the scientific method is to create scientific theories. The scientific theory, however, usually introduces an element which has not been or cannot be directly observed, and also, as we have seen, usually proves to have been too hasty a generalisation. Its function is to co-ordinate known phenomena and to predict hitherto unobserved phenomena. The extent to which it does this is the measure of its success as a scientific theory, and, since the primary object of the scientific theory is to express the harmonies which are found to exist in nature, we see at once that these theories must have an æsthetic value. The measure of the success of a scientific theory is, in fact, a measure of its æsthetic value, since it is a measure of the extent to which it has introduced harmony in what was before chaos.

It is in its æsthetic value that the justification of the scientific theory is to be found, and with it the justification of the scientific method. Since facts without laws would be of no interest, and laws without theories would have, at most, a practical utility, we see that the motives which guide the scientific man are, from the beginning, manifestations of the æsthetic impulse. The reason why certain facts and not others interest the scientific man, the reason why he makes a choice, is because truth without beauty is as uninteresting to him as to any other artist. In the words of Poincaré: "Le savant n'étudie pas la nature

parce que cela est utile ; il l'étudie parce qu'il y prend plaisir, et il y prend plaisir parce qu'elle est belle. Si la nature n'était pas belle, elle ne vaudrait pas la peine d'être connue, la vie ne vaudrait pas la peine d'être vécue."

A PHYSICIST ON PHYSICS

I

The well-meant and industrious efforts of professional metaphysicians to explain to men of science in what sense science is true, in what sense it has meaning and in what its value really consists, practically all suffer from the defect that men of science do not recognise the subject of investigation as being science at all. It is almost true to say that the professional philosopher is only convincing when he is talking about the Absolute, for that is a subject with which nobody else is concerned; but when he devotes his attention to subjects with which other people are familiar, it often becomes possible to put the book down before finishing it. Thus treatises on æsthetics are usually convincing to everybody but poets, painters and musicians, and philosophical writings on science are probably in great demand amongst classical scholars. Nevertheless, since philosophising on these subjects is an agreeable mental exercise, we find that some artists are now engaged in developing an æsthetic for themselves, and some

men of science are engaged in trying to find out what science is. In each case the work consists chiefly in making explicit processes which are instinctive. This fact is of the greatest importance, for, if the instinctive equipment be lacking, the results will inevitably be unsatisfactory. There are treatises on æsthetics, for instance, whose chief effect on the poet is to make him doubt whether the author could tell a good poem from a bad one ; this is an absolutely fatal objection. If poets cannot recognise what they call poetry as being the subject of the discussion, then, as a discussion of poetry, that discussion is worthless. Practitioners, whether artists or men of science, seldom have the inclination to uncover and dissect what is to them an instinctive and delightful process ; but it is quite easy for them to see (or, rather, to feel) that a suggested explanation is unsatisfactory, although they may find it wholly impossible to give reasons for their dissatisfaction. Nevertheless, when this dissatisfaction is due to an inability to recognise the subject-matter, the explanation must be condemned. It is perfectly possible, for instance, that psycho-analysis, by introducing a mother-complex, an inferiority-complex, and two or three more, might " explain " the Ode to a Nightingale. But if this explanation left out everything which made poets regard that composition as a poem, it would not be a satisfactory explanation.

We have treated this point at some length

because Dr. Campbell, in a recent valuable book on the Elements of Physics, insists that the physics he is talking about is that of physicists. He has endeavoured to supply a criticism of the terms used in Physics, to find what is meant by a Law, by a Theory, what a physicist means when he says a proposition is "true," or that something "exists," or that a theory has "meaning." Mr. Campbell is perfectly aware that all these subjects have already been treated by the professional metaphysician, but he claims, and we have no doubt that his claim is just, that he is speaking not only for himself but for the great majority of scientific men when he says that in these discussions he not only does not recognise the subject-matter, but he does not recognise any subject-matter. Such words as "reality" and "existence," as they are employed by metaphysicians, he finds productive of nothing but great discomfort and intense mental confusion. As he unhesitatingly rejects the hypothesis that metaphysicians are imbeciles, he thinks this confusion can be due only to the fact that these words are used by metaphysicians in senses quite different from those they bear to men of science. He has not been able to explain precisely in what the difference consists, since he has not been able to discover what meanings metaphysicians attach to these words. Accordingly he has confined himself to explaining the meanings these words have in science. The result is a subtle, fairly clear,

and frequently entertaining piece of analysis. He acknowledges that his two masters have been Poincaré and Bertrand Russell, and he shows complete familiarity with other writers of the kind. But part of his reason for publishing the book, he tells us, is that even the mathematical philosophers occasionally misrepresent science as the experimental physicist knows it. That they are mathematicians and not physicists is a little too evident in some of their conclusions. Thus Mach's idea that the object of science is to economise thought is only plausible, he thinks, to a mathematician ; and a fundamental proposition that Russell and Whitehead find quite necessary to thought Mr. Campbell does not find necessary at all. He thinks it quite likely, also, that scientific thinking is illogical, but not therefore invalid. The point of view, in fact, is that there are different kinds of minds with different needs and different satisfactions, and Mr. Campbell claims that physicists, for example, belong to a certain species and that the science of physics is something which exists in the minds of physicists. Therefore this book, as he insists, is not only written by a physicist, but it is written for physicists. He is confident that what he has to say will be found an explicit statement of their instinctive processes, and he thinks the highest compliment that could be paid to his book would be for physicists to say they knew it all before.

Now it is true that nobody but a physicist could

have written this book and that nobody ignorant of physics could understand it. It may also be true that none but a practising physicist could understand it with the intimacy that Mr. Campbell desires. But any reader who is not, in Mr. Campbell's sense, half-educated (the other half consists of science—preferably physics) will find the book not only valuable, but delightful. The slight touch of *brusquerie* that the metaphysician or the equally unfortunate "half-educated" person might attribute to Mr. Campbell from the above exposition is not in the least that of the horny-handed son of toil, but is the half-humorous impatience of a subtle and vigorous thinker who is by no means naïve. There is no reason why the audience that reads Poincaré's popular four volumes should not also read this book, and there are many reasons why it should. Many of the questions raised there are here developed more fully; most of the questions, in fact, raised by the speculations of such men as Poincaré, Russell, Mach, etc., in so far as they affect science, are here given systematic treatment. We hope to devote a future article to the exposition of some of Mr. Campbell's more interesting results; we are concerned here to indicate the nature and scope of the book.

The present volume is in two pretty distinct parts, the first part being concerned with the propositions of science, and the second part with measurement. These are to be followed by Part

III. on Space and Time, Part IV. on Force, and Part V. on Energy, although, regarding these parts, Mr. Campbell says: "I have not the remotest idea when, if ever, they will be published." Without anticipating a future discussion of the more technical parts of Mr. Campbell's work, we may refer here, because of the general interest taken in the subject, to the explanation he gives of the fact that while the outside world resolutely marks off Science from Art, yet this distinction is not at all clear to scientific men. It is difficult, for example, in studying the life of a great man of science, to resist the conclusion that his incentives and satisfactions are indistinguishable from those of a great artist. Yet it seems to be undoubtedly true that a work of Art is something personal, whereas Science is obviously impersonal. Mr. Campbell asks us to distinguish between truth and meaning. The truth of science is something impersonal, but its meaning is personal. The achievement of Newton and Maxwell is as personal as that of Giotto, Shakespeare and Bach. Their dreams were not less personal, nor less delightful, and it is nothing to their discredit that their dreams also came true. And the fact that the meaning of a scientific theory is something that exists, perhaps, only for men of science, has an obvious parallel in Art. The following passage from Mr. Campbell's book is one to which every man of science would give instant assent:

Nobody who has any portion of the scientific spirit can fail to remember times when he has thrilled to a new discovery as if it were his own. He has greeted a new theory with the passionate exclamation, " It must be true ! " He has felt that its eternal value is beyond all reasoning, that it is to be defended, if need be, not by the cold-blooded methods of the laboratory or the soulless processes of formal logic, but, like the honour of a friend, by simple affirmation and eloquent appeal. The mood will and should pass ; the impersonal enquiry must be made before the new ideas can be admitted to our complete confidence. But in that one moment we have known the real meaning of science, we have experienced its highest value ; unless such knowledge and such experience were possible, science would be without meaning and therefore without truth.

II

What kind of Physics would be developed by a man alone on an island ? We are assuming, of course, that this favourite figure of speculative writers enjoys the properties usually attributed to him ; he is remarkably intelligent, and can create by a word any scientific apparatus he requires. The point is that he has no need to take into account the judgments of other people. Let us choose an experiment designed to make clear the consequences of his isolated state. Suppose our islander, after looking at a red patch, glances at a white ceiling. He sees a green patch. Now suppose that he heats a copper wire in the flame of a Bunsen burner.

The flame turns green. Will our islander proceed to construct a physics which shall embrace both these observations? Before we can answer this question we must consider why our own physics distingushes so sharply between them. In the first place, it may be said that all observers, except the man who contemplated a patch of red, agree that the colour of the ceiling is unchanged, whereas, in the case of the copper wire, all observers agree that the flame has turned green. In the first case, therefore, we say that there has occurred a change in the observer, and in the second case a change in the flame. We invoke the criterion of universal assent. But it can readily be shown that we have not, in fact, invoked this criterion, for in saying that the flame has turned green, we have left out the testimony of colour-blind persons. Not everybody would agree that the flame has turned green, and on what principle are we to decide between the conflicting opinions of different observers? Mr. Campbell's examination of this question appears to take us to the root of the matter. Universal assent is involved, but also something more, and it is the something more which will probably enable our islander to form a physics like our own. Let us first consider the way in which universal assent is involved in science.

We must obviously leave out judgments of colour; similarly, science does not now measure electrical quantities in the manner of Cavendish, by comparing the intensities of electric shocks

experienced by the observer. Science makes a choice of the judgments it shall consider ; it does not even embrace all judgments for which universal assent may be obtained. The judgments on which science is based, and for which universal agreement may be obtained, are divided by Mr. Campbell into three groups : (1) Judgments of simultaneity, consecutiveness and " betweenness " in time ;* (2) Judgments of coincidence and betweenness in space ; (3) Judgments of number, such as, The number of the group A is equal to, greater than or less than, the number of the group B. Now it is judgments of this kind that are involved in physical observations : the deflection of a spot of light on a scale, the reading of a stop-watch, and so on. These judgments are fundamental to science and are such that universal assent may be obtained for them. Let us now consider the case of the copper wire in the Bunsen flame. We have said that not all people will agree that the flame has turned green. But the light from the Bunsen has other properties than its colour ; it has a measurable refrangibility and a measurable wave-length. The important point for physics is that all observers, both " normal " and colour-blind, would agree on these measurements, since they are connected with the fundamental judgments mentioned above. The fact that different observers associate these same measurements with different colours is a fact

* Assuming, in accordance with the principle of Relativity, that all observers have the same motion.

of no importance for physics; "colour" is not a notion essential to physics at all; when phrases containing such words as "red" or "yellow" occur in physics they may always be replaced by words depending for their meaning solely on fundamental time, space and number judgments. It is for this reason, then, that science builds on perfectly sure foundations; its foundations can only be denied by an imposter, that is, by one whose actions show that he actually believes what he says he denies. Now, how does this apply to our islander? We may assume that he can measure refrangibility and wave-length. He finds that, in these particulars, the light from the ceiling is unaltered, while the light from the Bunsen flame is altered. But these observations have no greater support than his colour judgments. On both occasions the only testimony is his own. But he would notice a great difference directly he began to establish the laws connecting these phenomena. The laws derived from the second set of observations would be much more satisfactory than those derived from the first set. He would undoubtedly prefer them and would unhesitatingly adopt them. When it is put in this way, there certainly seems something arbitrary about the process by which science selects its fundamental judgments. They are selected because they fall neatly and satisfactorily into laws. Mr. Campbell further suggests that the laws used in science are selected from amongst other possible laws because the selected

laws fit into theories, "the form of which is dictated chiefly by preconceived ideas of what a theory should be." It may be stated at once that Mr. Campbell admits the presence of an arbitrary element in science, but it is precisely his case that this arbitrary element gives to science its value.

We cannot here summarise his exposition, because it would be unintelligible except to readers with a scientific training, since Mr. Campbell has adopted the very sound method of analysing the actual laws and theories current in physics. We may indicate, however, the general lines of his investigation. He attempts to analyse the kind of relation involved in a scientific "law." It has been generally assumed by philosophers that this relation is the "causal" relation, but, in fact, it is very doubtful whether this relation is ever used in the statement of laws. It is a very special kind of relation, and its supposed importance to science seems to rest on a confusion between the psychological process in an observer performing an experiment and the relation stated to exist between his observations. Thus, in Ohm's Law, does the potential difference enter as cause or effect of the current? The question is sufficient to show that the causal relation is not concerned. Mr. Campbell admits that he has not succeeded in making a final analysis of the propositions called laws, but we think that he has certainly established several points of great value. It is more to our present purpose, however, that this analysis shows more

clearly how an arbitrary element enters into scientific laws. A law does not simply relate concepts in a manner consistent with observation; it would be perfectly possible, for instance, to replace Ohm's Law, expressing simple proportionality between current and potential difference, by a much more complicated expression which should agree equally well with observation. There are always several laws which will satisfy the observations; the one that is chosen is chosen for its simplicity, i.e., because of the mental satisfaction it affords. The fact that it does fit the observations gives it what Mr. Campbell calls its "truth," and the fact that it affords intellectual satisfaction gives it what he calls its "meaning."

When we pass from laws to theories we find that the element of "meaning" becomes much more prominent. Now the truth of a law is something that rests on universal assent; this is not the case, however, for the meaning of a law. It may be that the contemplation of Ohm's Law gives you no satisfaction whatever; if it satisfies me, however, then to me it has meaning. It is only necessary, therefore, that scientific laws should have meaning for scientific men; their truth, however, is the same for all. When we come to consider theories we find that, concerning their meaning, there is much more difference of opinion. This difference, in fact, almost follows national lines, so that of the two great classes of theories, the "mechanical" and the "mathe-

matical," the former is largely a product of British physicists, while continental physicists prefer the second type. Mr. Campbell analyses very acutely the differences between the two classes as well as the elements they have in common. As he says, there may be a "taste" for certain kinds of theories, as there is a taste for oysters. The result of this analysis is to show very clearly in what respects science is impersonal and in what respects personal; it also helps to make clear what science is. It is true that the impersonal element in science is the most important, in this sense, that if any law or theory can be shown not to be true, then, however much meaning it may have, it must be at once rejected. It is also true that it is the meaning of laws and theories, particularly theories, which gives them their value to scientific men. We therefore reach once more the conclusion, sufficiently familiar, but seldom so satisfactorily prepared, that the value of science is in the æsthetic satisfactions it affords. In Mr. Campbell's words, "Science is the noblest of the arts."

SCIENCE AND CULTURE

The influence of scientific discoveries on that vaguely defined complex of beliefs and intellectual interests called culture seems, at first sight, to have something paradoxical about it. There can be no question that this influence is very widespread, and there can be as little question that ignorance of scientific discoveries is equally widespread. If our admittedly cultured classes were submitted to such a *questionnaire* as the workers in Sheffield were recently called upon to answer, we should doubtless find that such questions as Who was Dante? Who was Plato? would act like holes in a dam; but it is to be feared that the questions under the heading *Science* would evoke the merest trickle of information. And yet many of the questions in other parts of the *questionnaire* would be answered very differently were it not for those scientific discoveries of which the examinee can give no satisfactory description. The apparent paradox is resolved by remembering that it is only the broadest generalisations of science, and only certain aspects of those, which exert a marked

influence on the rest of a man's beliefs. The varied and highly complicated studies which make up modern astronomy, for instance, can be known, in any real sense, to but a few specialists ; the one significant thing, for purposes of general culture, that emerges from these studies, is that the earth is materially insignificant in the universe. We need not mind if so much knowledge and no more percolates through the barriers of a literary education ; the damage is done ; the rest of the man's beliefs begin to be profoundly affected. In the papers on geology and biology the majority of cultured people would fail ; they would all be amused, however, at the idea that the earth was formed in 4004 B.C. and that man was a special and separate creation. Psychological studies have not yet reached, perhaps, a great and easily understood generalisation, but there is a growing charity vis-à-vis the "criminal classes" and other moral outcasts. Our Victorian parents' hearty condemnation of everybody they disliked is now just a little more difficult. Such generalisations as we have been mentioning are important to general culture because of what we may call their perspective effect. Their bearing on the rest of a man's mental furniture is not direct ; they put the furniture in a different setting. A change of residence, if the difference between the two houses be sufficiently marked, may well lead to a change of habits, and the furniture which looked quite well in four rooms may seem a little inadequate in

forty. Those writers who declare that there is no "real" conflict between science and religion, for instance, may be perfectly good logicians; the point is whether a particular religion looks adequate in the modern universe of science. It is not a question of destroying the furniture; it is whether the contents of a bijou villa adequately furnish Salisbury Plain. The influence of science on philosophy is similarly indirect. Perhaps there is no philosophy which does not still find defenders; our objection to many of these philosophies is not that they are illogical, but that they look so funny.

When we come to study the influence of science on the arts we see that there is yet another way in which science modifies culture. Many of the pleasurable emotions associated with the arts are not unknown to the student of science. The study of such sciences as astronomy, physics or biology awakens emotions not readily distinguishable from those evoked by even the greatest works of art. It is as if the universe with which science deals was itself a work of art; it is, to an increasing number of people, the greatest of all works of art. Such students often acquire a new standard of æsthetic excellence. Darwin's indifference to poetry in his later years was probably the result, not of the atrophy of a faculty, but of its fuller exercise elsewhere. The young William Thomson, reading at night in the library, and drawing great breaths of rapture over Lagrange's *Mécanique Analytique*, was experiencing emotions probably

not very different from those of Swinburne when reading Shakespeare. Before such satisfactions become accessible to the ordinary cultured classes more is required than that vague acquaintance with outstanding generalities to which we have referred. In such a science as astronomy the mere results are often sufficiently attractive to rouse pleasurable emotions in the reader, although the actual march of the investigation by which the results were obtained is often of equal interest. At the present day both results and the broad lines of the investigations are in many cases accessible to the ordinary cultured person, with the result that his intellectual interests are added to, or at least find a new field for deployment. A greater number of æsthetic objects people his world, and it may even happen that the new arrivals affect the estimate in which he held the old. He may discover an unsuspected futility in some of his earlier occupations ; he may, in fact, change his ideals of culture.

But it is, in truth, impossible to trace precisely the effect on an individual of a new belief or of a new interest. Psychologists have made us aware of the fact that the mind is not only immensely complex, but that the connections between its elements are often of the most unsuspected character. Destruction of an old belief or the grafting of a new interest may issue in results as unlike their cause as the butterfly is unlike the chrysalis. The effect of the impact of science on the old culture cannot be foreseen ; it has, how-

ever, already produced such changes that the culture of the comparatively near future will probably differ from ours by more than ours differs from that of Babylon.

JAMES CLERK MAXWELL

The place that will be held by James Clerk Maxwell in the history of physics is not easy to determine. That it will be a very high place is obvious, that he will emerge as the greatest of the physicists of the nineteenth century is probable, but the student of Maxwell must feel that this kind of ranking is somehow irrelevant, or likely to become irrelevant, to his peculiar effect. The unique impression produced by Maxwell's achievement is not adequately described by being referred to his "originality." There are different ways of being original; it is not a sufficiently penetrating term. A number of Maxwell's scientific contemporaries were original men, but one is conscious that they had more in common with one another than Maxwell had with them. An exception from this statement is found in W. K. Clifford, who, as has often been remarked, had a genius curiously akin to Maxwell's. Both men were exceptionally *independent* thinkers, both men resisted the attraction of the high road; both men, if the term may be permitted, had a personal and unique angle of approach to the problems of

their time. But this, though true, is not a sufficient description. It is important that in neither case do we feel their individual quality to be an eccentricity; their work has a power, and, still more, a comprehensive serenity, which is never the product of mere oddity—the oddity, for instance, of a Samuel Butler. If we try to get closer to this elusive and important characteristic we do not meet with much success; but we may suggest that the ideas of these men have the effect of springing from an unusually rich, subtle and comprehensive *context.* The fundamental ideas of the science of their time were subtly modified by reception into these minds; they were connected in a personal and unusual web of implications.

It is doubtless worth noting in this connection that Maxwell, unlike most of the scientific men of his time, was genuinely interested in metaphysical speculation. This was not merely another interest of his; it was, at most, another field of attention; he brought the same attitude of mind to all the objects with which he was concerned. We cannot make an exception even in the case of his religious views; to this man the problems of metaphysics, of physics, of morality, are almost arbitrary divisions of the one object of his thought. He was expressing a real difference from himself when he said that some men seem to have water-tight compartments in their minds. When we study the kind of homogeneity characteristic of Maxwell's mental life it is easy to understand those who call him a

mystic. Even as a purely scientific man, his rational faculty, as evidenced by his mathematical reasoning, was a distinctly more fallible thing than his intuition. This is not to say that he was not a fine mathematician, but it is his intuitive grasp of a physical problem which gives him his high position, and not his purely mathematical verifications. His mathematics, in fact, was not always impeccable, as Sir Joseph Larmor points out in the new edition of *Matter and Motion.* But it is characteristic of Maxwell, that, even when his proofs were faulty, his results were usually sound. His own way of confirming a difficult intuition was not to provide a formal mathematical verification, but to make appeal to easier intuitions —in fact, to construct mechanical models. He always liked to *see* the way things worked. It is important to remember that this desire for a particular kind of verification was not due to any lack of power to form abstractions ; it was due to something quite different, to a lack of ease when faced by a purely logical chain of deduction. On Maxwell's famous *Treatise on Electricity and Magnetism*, Poincaré comments that its difficulty resides precisely in its great abstraction. It is this presentation of his theory to which one has to turn ; nevertheless Maxwell, as if for his private satisfaction, developed some extremely complicated models which seemed to him to make his theory clearer. It was doubtless this combination, a great power of abstraction on the one hand, and a desire

for very definite, even unnecessarily definite, confirmation on the other, which enabled him to be at once extremely original and remarkably sound.

In his boyhood he was constantly making all kinds of experiments with common substances, drawing complicated diagrams, constructing solid geometrical figures, even knitting elaborate pieces of wool-work ; practically all these pursuits were dictated by the same desire, the desire to see an abstract principle embodied in a concrete instance. No man was less at the mercy of words. But it was, nevertheless, the abstract principle with which Maxwell was concerned ; he merely wished to be quite sure that he understood it. His occasional trick of supplying an unexpectedly simple proof of a difficult theorem is due to this habit of realisation. Platitudes acquired a wealth of implication in Maxwell's hands. During his student life at Cambridge, when he seems to have been chiefly occupied in making a survey of things in general, we find the same desire to reduce everything to a few principles ; but the principles must first stand a rigorous examination. Merely vague unifications provoked his irony, and where no principle could be made to work, then, in spite of his love for coherent and inclusive systems, he would admit ignorance. And, in spite of his need for principles, and the tenacity with which he clung to those that met his need, he claimed no " absolute " quality for his beliefs. In his own words, " Nothing is to be *holy ground* consecrated to Stationary Faith,

whether positive or negative." And, later, "Again, I assert the Right of Trespass on any plot of Holy Ground which any man has set apart. . . ." Such questioning as Maxwell applied to himself was to be applied to all other men. He was conservative, but not on exterior authority. His scepticism was, in truth, very profound, and it was always present. It informs his criticism, which is often extremely penetrating. The letters he wrote on the death of his friend Pomeroy, shortly after Maxwell had become a Fellow of Trinity, are very instructive from this point of view. His distrust of the "rationalisations" that men give of their beliefs extends to the beliefs themselves. As he says, men "are ignorant even of their own true faith till something brings it into action." This was a deep-rooted conviction with him, and is responsible for the flavour of irony which is never long absent from his comments on philosophic matters, indefatigable student as he was. He can direct this scepticism against himself, as in the entry in his programme of future study: "4. Metaphysics—Kant's *Kritik of Pure Reason* in German, read with a determination to make it agree with Sir W. Hamilton." On another occasion he writes to a friend pointing out that, in reading an author, he had to find out first of all, not what the author meant, but that it was not what he was convinced must be meant. A little experience of criticism persuades us that this is, indeed, a very necessary procedure.

This aspect of Maxwell, as a critic at large, as it were, would well repay study, and it is unfortunate that our material for it is contained in a scarcely ideal biography. He differed from the run of scientific men, whose absorption in one pursuit makes their mental life unrepresentative; his chief problems are not found in his scientific writings, and they are the problems of us all. There was nothing superficial in Maxwell, and he had no easily won conclusions. It is the path he followed that gives interest to his goal. We should like to know, for instance, what experiences, what reflections, enabled him to write: "Long ago I felt like a peasant in a country overrun with soldiers, and saw nothing but carnage and danger. Since then I have learned at least that some soldiers in the field die nobly, and that all are summoned there for a cause." That Maxwell, either suddenly or gradually, developed a mystic consciousness of life, is borne out by many passages of his correspondence. We can attach no other significance to his description of his "nostrum": "an abandonment of wilfulness without extinction of will, but rather by means of a great development of will, whereby, instead of being consciously free and really in subjection to unknown laws, it becomes consciously acting by law, and really free from the interference of unrecognised laws"; and his letters to his wife, dealing with passages from the Bible, abound in interpretations which are indubitably mystical. Yet we have no evidence that he was

acquainted with the literature and terminology of mysticism ; he is speaking of personal experiences, not of acquired doctrines.

The maintenance of a mystical outlook on life, together with a perfect realisation of the implications of physical science, was accomplished, in Maxwell's case, by denying the ordinary conception of the *direction* of scientific progress. It is the idea which would inevitably occur to him, for it is the peculiar merit of his own work that it was not the result of straightforward progress. He made a new way of thinking necessary just as, in our own time, Quantum Theory and Relativity Theory have fundamentally disturbed our most unquestionable assumptions. The way Maxwell actually approached the problem we have mentioned was by insisting on what he called, by a mathematical analogy, the " singular points " of existences, that is, the points where the equations break down, and he postulated that the more there were of these singular points the higher the rank of the existence. At a " singular point " influences which are usually negligible may assume a dominating importance, and Maxwell saw the science of the future as being largely concerned with these lapses in continuity—as, in fact, science since his time has been. In this way he escaped determinism. In his own words :

If, therefore, those cultivators of physical science from whom the intelligent public deduce their concep-

tion of the physicist, and whose style is recognized as marking with a scientific stamp the doctrines they promulgate, are led in the pursuit of the arcana of science to the study of the singularities and instabilities, rather than the continuities and stabilities of things, the promotion of natural knowledge may tend to remove that prejudice in favour of determinism which seems to arise from assuming that the physical science of the future is a mere magnified image of that of the past.

This speculation, the problem of evil, and in what sense the individual may be said to persist in Time, are the kind of questions which concerned him during the last years of his life. It would be merely fanciful to mention these things as evidence of that " context " of which we spoke, but we think it is possible to understand more intimately the origin of the Electromagnetic Theory of Light if we remember that it originated in a mind which also constantly entertained these other, and apparently disconnected, speculations.

ASSUMPTIONS

I

It has been remarked that man's senses were given him, not to philosophise with, but to help him in the struggle for existence ; Boltzmann, the great German physicist, was frankly distrustful of many of the natural motions of the mind. He could admit that Science, although often very abstract, had a certain validity, since it issues in the prediction of events which are accessible to sense perception. But philosophy, he insisted, was in an altogether different case, and he thought the chances considerable that its impalpable conclusions were the merest moonshine. It is a speculation that must have exercised everyone who has whole-heartedly accepted the evolutionary account of the rise of intelligence. Why should this instrument be adapted to other than its original uses ? Doubts of this kind, however, are both too vague and too comprehensive to serve any useful purpose. They do not tell us in what way and to what extent our intelligence is untrustworthy ; they do not enable us to make one step towards drawing

up an Index of Forbidden Subjects. At the most they enable a man with a constitutional dislike of philosophic speculations to indulge his contempt for that occupation with an easy conscience. Nevertheless, a tincture of this doubt is very wholesome, and more particularly if it be the result of an acquaintance with the history of human thought rather than the product of a kind of lazy *a priori* scepticism. A student of the history of science, for instance, is inevitably led to reflect on the curious nature of the barriers to further advance which the mind itself has set up. It is as if the mind could only take exercise within some imaginary prisoner's yard, and that the great advances were really the result of liberations. These liberations are only partial; the mythical boundaries are set a little further off, but it is agreed that the high walls exist.

It is interesting to review the progress of Science from this point of view, to see it as a gradual secession from unwarrantable assumptions. The exceedingly cautious, the almost groping character, of the advance of knowledge, becomes very apparent. And, although such a survey may lead us to become very conscious of this particular mental limitation, we are not one whit nearer being enfranchised. It is still the prerogative of genius to be innocent, to turn surprised eyes on one of our most arbitrary assumptions, and to say: But that is not necessary. The history of Astronomy, of course, provides some of the best examples of

mental prison yards. That the planets must move in circles because the circle is the perfect figure is an assumption now sufficiently remote from our acquired sense of probability to seem exceedingly strange. That it was an assumption possessing a high degree of obviousness is apparent from the fact that even Copernicus did not question it. The attempt to enter into this assumption, to see it as obviously reasonable, would be a useful exercise for the historian, since it involves, very largely, a reconstitution of the mental life of that age. It acquired its obvious character from the fact that it *fitted in* ; it was the natural companion of a great number of other equally obvious assumptions ; it was not an isolated eccentricity of the mind. It is for that reason that Copernicus never freed himself from it, and that Kepler only succeeded after a difficult struggle. Kepler was required to question not merely an isolated doctrine, but to escape from a veritable *Zeitgeist.* The Inquisitorial examination of Galileo, also, was not directed merely to correcting the erroneous statement of an isolated fact ; it was, in truth, a whole system of thought that stood on trial. It is this double aspect of any given abandoned assumption that accounts for our unimaginative surprise on learning that very intelligent men once mistook it for an obvious truth. We are judging the assumption, not on its own merits, as it were, but from the standpoint of an alien system of thought.

We can form a juster estimate of the degree of

credulity manifested by the contemporaries of Copernicus by considering assumptions that have been but recently questioned, or rather, which have only recently been generally questioned. The assumptions regarding animal psychology form a vivid example. Such men as Darwin and Romanes found it quite natural to assume that the emotions and many of the intellectual processes of which they were conscious in themselves furnished an adequate key to animal behaviour. It is an assumption which the average educated man of to-day makes quite readily, although he may not share Aristotle's views on the perfection of circles. We now know that there is no reason whatever to suppose, for example, that the psychology of snails has the slightest resemblance to the psychology of human beings. We may be confident that, in a very few years, the assumptions of Darwin and most other people will appear almost inexplicably gratuitous. It will take longer, we think, for the Freudian ideas about man himself to become acclimatised ; man will take a long time to learn that in trusting his immediate awareness of himself he is making a number of unwarrantable assumptions. The system of thought into which his present assumptions fit is so profound and extensive that it is impossible, even now, to picture the thoroughly enfranchised man.

A general acceptance of the Einsteinian ideas of space and time is easier to predict. The current conceptions of space and time, although Euclidean

when reduced to a logical scheme, are not, in fact, present as a logical scheme in the mind of the ordinary man. He is sufficiently vague about his fundamental assumptions to offer no strenuous resistance to their subtle modification. We think that part of his general bewilderment about Einstein's space and time is due to his bewilderment on thinking about space and time at all. His assumptions on these questions, whatever those assumptions may be, are not really part of a general scheme of beliefs. Nothing that greatly concerns him is incompatible with non-Euclidean geometry, and we confidently expect that the grandchildren of the ordinary man will as blandly believe they have swallowed Einstein as the contemporary ordinary man believes he has swallowed Euclid. For an assumption which is not an integral part of a general scheme of thought is readily abandoned. It is the lopping of connections which the mind resists. It is no paradox to say that the mathematician and philosopher finds it harder to accept Einstein than does the ordinary man. That is because the mathematician's acceptance involves both believing more and disbelieving more.

II

Probability is, of course, the guide of life. If all our assumptions were expressed, we should find the phrase " it is reasonable to suppose " occurred more frequently than any other, whether we were

engaged in crossing a street or in writing a philosophical essay. Yet our perception of the reasonableness of anything rests on a sentiment which is often very delicate and extremely difficult to define. The mathematicians have succeeded in giving exact expression to some of the simplest manifestations of this sentiment, but most of the cases we are called upon to solve in ordinary daily life cannot be dealt with by their analysis. It is the great strength of science that it builds wholly upon this sentiment. We are not called upon to "transcend" reason by faith; we are asked to believe nothing that sins against our sense of probability. It is admitted, of course, that there are scientific theories that do not sound reasonable on a first hearing; indeed, they sometimes outrage common sense, and every scientific engineer knows the difficulty of persuading the "practical" man that the obvious thing is not always the right thing. Nevertheless, it is claimed for science that, on the evidence, its conclusions are the most reasonable ones even when they are wrong. The sense of what is reasonable depends upon the evidence, but the word "evidence" must often be taken to include a great deal of which the mind is not fully conscious. It was at one time thought quite reasonable that the heavenly bodies should move in circles round the earth. The belief was not wholly a matter of astronomical evidence. It was considered that there was something peculiarly and inherently reasonable in circular motion for

heavenly bodies. We can see that this expectation was connected with the æsthetic properties of the circle, and we now think that expectations based on such considerations are, in astronomical matters, illegitimate. Something akin to such considerations still plays a part in science, however, although in a less obvious form. Other things being equal, a simple explanation of natural phenomena is preferred to a more complicated one, although, as Fresnel remarked, there is no *a priori* reason to suppose that Nature takes any account of analytical difficulties. The history of the Copernican theory of the solar system is instructive from this point of view. The notion that the Earth and other planets went round the sun immediately made a number of puzzling things clear. It seemed, on the whole, a very reasonable notion. It was attended, however, by one great difficulty. If, at the end of six months, the earth were really at opposite ends of a long line, it should follow that the stars, viewed from these two points, should seem to shift their relative positions in the sky, just as the trees in a wood seem to change their relative positions as we pass them in a train. Tycho Brahe, one of the greatest astronomers who ever lived, was so impressed by the fact that this expected change does not occur, that he could not accept the Copernican theory as it stood. He invented a curious hybrid theory of his own, according to which, while the other planets went round the sun, they, together with the sun, revolved round

the earth. He does not seem to have made many converts to this view; it somehow offends one's sense of probability. The Copernican hypothesis persisted, in spite of the difficulty we have mentioned, but not without causing considerable mental discomfort. When Horrebow at last thought that he had obtained evidence of the apparent annual motion of the stars he published his discovery under the title *Copernicus Triumphans*. It was found, however, that the supposed differences were caused by temperature changes affecting the observer's clock, and the old difficulty persisted. It might be thought that the correct solution was obvious; one had only to assume that the stars are so far away that, with such instruments as were then used, their apparent motion is imperceptible. We now know that this solution is the right solution, but in the eighteenth century it did not appear a reasonable solution. It was felt that if the stars were really at such immense distances as this hypothesis required, then Nature showed a grave lack of economy in space. Such enormous stellar distances pointed, so far as these astronomers could see, to a most unreasonable waste of space. No farmer would behave in such a fashion, and although the eighteenth-century astronomers would have denied that they viewed the universe as a gigantic farm, yet this delicate and elusive notion of what is reasonable was, in this case, greatly influenced by farming considerations. It is not possible to form reasonable ex-

pectations except on the basis of experience, and sometimes the most irrelevant considerations play a part in our estimate.

As instruments improved, however, the expected motion was observed, and the distances of some stars calculated. They proved to be enormous; the great waste of space does occur. God is not a farmer. This being established, one could approach the general problem of stellar distribution free from certain prepossessions. One's sense of the reasonable acquired a different orientation, as it were. But it still remains reasonable to suppose that the brighter stars are, on the whole, nearer to us than the fainter stars. This assumption must, however, be employed with caution. If a list be formed of the nearest stars from amongst those whose distances have actually been determined, we reach some rather unexpected results. Knowing the apparent magnitudes of these stars, and their distances, we can calculate their actual luminosity compared with the sun as a standard. The apparent magnitudes range from Sirius, which is considerably brighter than a first-magnitude star, to stars of more than the ninth magnitude, that is, to stars quite invisible to the naked eye. Some of the nearest stars may be fainter yet, for determinations of the distances of stars fainter than magnitude 9.5 are lacking. The actual liminosities of these stars range from forty-eight times that of the sun to four-thousandths that of the sun. The actual distribution of the nearer stars is not at all

that which would appear reasonable if we were guided by considerations of apparent brightness. Some of the very brightest stars, such as Canopus, must be at inconceivable distances, and their actual brightness must be thousands of times, perhaps very many thousands of times, that of the sun. Here again our unsophisticated notion of what is reasonable is apt to be more of a hindrance than a help. Excellent as a guide through not too unfamiliar country, it is apt to lead us sadly astray when we advance into completely unknown territory. Nevertheless, it is the only guide we have.

III

If we contrast ancient with modern scientific theories we find that the chief distinguishing characteristic of the former is that they employ principles drawn from other branches of knowledge or speculation. It would be, perhaps, rash to say that modern science, in all its branches, is yet completely autonomous; sometimes, for instance, it seems to make assumptions which are the result of an uncritical philosophy, but even the grossest of these examples, compared with many celebrated early scientific theories, shows how great is the purification that has been effected. The chief error of the old speculators consisted in imagining that the world is a more obvious unity than we have now any reason to

suppose. Hence they were always willing to argue by "analogy," comparing terms between which we cannot now find the slightest resemblance. The method was not only illegitimate, but sometimes led to quite unnecessary complexities of explanation. The Ptolemaic system of astronomy, for instance, conceived as the theory that the heavenly bodies revolve round the earth, was a perfectly reasonable and satisfactory theory. It was capable of explaining all the observed planetary motions, except a few minute irregularities requiring precise measurements for their detection. Its proper development required, of course, complete docility in face of the facts. But in its actual development it was forced to accommodate itself to quite other considerations. It had to take into account the venerable principle that, the celestial bodies being obviously sublime, incorrupt and perfect, their orbits must be perfect and described with uniform velocities. The only possible perfect orbit was as obviously a circle. Hence the Ptolemaic theory was loaded with the task of explaining the observed heavenly motions on two grounds: first, that the earth was stationary and at the centre of the system, and second, that the planetary orbits were circular and described with unvarying velocities. Alternative hypotheses were not only stupid but impious. The task thus set to the early astronomers was one of considerable difficulty.

The observed path of a planet, say Mars, or

Jupiter, or Saturn, is by no means simple. If its motion amongst the stars be watched from night to night it is seen to be moving sometimes from east to west and sometimes from west to east. Further, in changing its direction of motion it does not retrace its path amongst the stars. Its actual observed path exhibits irregular loops, and, more rarely, a twisted line. It was at once obvious that a circular orbit, traversed with uniform velocity, would not suffice to explain these appearances. Nevertheless, the principle must be preserved. The astronomers overcame this difficulty by a device that strikes one as being almost disingenuous. They imagined a small circle whose centre traversed the circumference of the big circle with a constant velocity and round whose own circumference the planet moved with a constant velocity. By assigning suitable velocities to these two motions the crude features of the planet's actual observed motion could be represented—it would sometimes be retrograde and sometimes direct. This is ingenious, but it is questionable whether it preserves the principle. The planet's motion is obtained by circular motions, it is true, but it is not itself a circular motion with reference to the earth as centre. The astronomers have entered on a slippery path. We view them with the same suspicion with which we watch a Broad Churchman expounding the Thirty-Nine Articles. But they had to go further. The theoretical and the observed motions did not

fit well enough. On the little circle it was necessary to imagine a still smaller circle, and to place the planet on its circumference. After all, this interpretation of "circular motion" once admitted, there was no reason why it should not be followed up. But progress in this direction soon came to a halt. It became evident that this method would not, by itself, reconcile observation and theory. The principle had to be strained again, and this time in an almost indefensible manner. It was declared that the big circle was eccentric with respect to the earth and that the little circles were eccentric with respect to their supposed former centres. This assertion must have been a great strain on the faith of the orthodox believer. He may well have wondered whether, by this time, the pure doctrine of his fathers had not been subtly undermined. Circular motion was still preserved, in a way, it is true, but with so many circles, and their centres all over the place—this must have appeared something very different from what he supposed the principle to mean.

The same difficulty was felt by simple minds in modern times, when the correct explanations of statements in Genesis were worked out by the theologians. And just as the simple story of the Creation in Genesis became transformed into an extremely obscure and ambiguous anticipation of the discoveries of Geology, so the interpretation of circular motion advanced from complexity to complexity. Immutable principles must exist,

of course—it is part of the glory of man that he should have been able to discover so many of them—but they sometimes seem more trouble than they are worth. The old astronomers found that yet again a more liberal interpretation must be given to the principle of circular motion. This time it was found that the circles do not all lie in one plane. Each circle has its own plane, which may be inclined at any angle to the others. By this time the theorists, whom we might call the "commentators," had forged a very powerful method. Circles could be multiplied; their centres could be placed anywhere; their planes could be inclined at any angle. The rich content of the principle of circular motion was now fully revealed. With all these variables to play with a very close correspondence between theory and observation was effected.

The rise of the "higher criticism" of this system leads to the history of modern astronomy. It is to be noted, however, that the first higher critic, like the first higher critics in other departments, was not wholly emancipated from his early teaching. Copernicus effected the immense revolution of placing the sun in the centre of the system, but he did not abandon circular motion. So he had to retain parts of the epicyclic apparatus. The revolution was first completely effected by Kepler, but even he conducted his early researches as a semi-believer, a kind of very Broad Churchman. He made nineteen successive attempts to explain

the motions of Mars by the arrangements of eccentric and epicyclic motions, and only then did he frankly throw the great principle of circular motion overboard, and state that the actual paths of the planets were ellipses. And so, in a few years, a great immutable principle, a whole system of beliefs, the industry and thought of generations went for nothing, and now exist merely as an occasional cold reference in a treatise on Astronomy to the Ptolemaic system as a "monument of misplaced ingenuity."

IV

We may divide scientific theories into two classes, which have recently been distinguished by Einstein as theories of construction and theories of principle. His own theory of relativity is a theory of principle, and its attraction resides in its logical perfection. Such theories, whatever charm they may have for the logician, are not, man being constituted as he is, felt to be sufficient. A principle which natural phenomena obey, and which enables equations to be deduced expressing the relations between phenomena, is, to a few austere souls, all with which science need concern itself, but the majority of men require, in addition, something they call an "explanation" of the relations deduced from the principle. They desire to see events described in terms with which they are familiar. Thus, a description of the behaviour

of the material universe in terms of the mutual impacts of little billiard balls would afford genuine satisfaction to the mind, and important advances have been made in science by the attempt to describe phenomena in these terms. The assumptions which underlie some such attempts may seem, to the logician, preposterous, but there is no doubt that the mind is impelled to make such assumptions. Our familiarity with the motions of matter in bulk makes it quite natural that we should endeavour to give, as far as possible, dynamical explanations of events, although, if we stop to ask ourselves why nature should be flexible enough to admit of descriptions in such terms, we are at a loss for an answer.

The history of theories of the æther is particularly instructive from this point of view, because the irrational nature of the impulse is here most clearly apparent. The attempt to explain phenomena in terms of an æther has led to some very remarkable theories of the nature of matter itself. It has been supposed, for instance, that the ultimate particles of matter are vortical whirls in the æther, or, again, points of a very special kind of strain in the æther. Nevertheless, a theory of the æther is regarded as unsatisfactory which is not couched in terms of the observed behaviour of ordinary matter as we know it. A dynamical explanation is always sought after, and a great part of the scientific effort of the nineteenth century was devoted to describing the æther as an elastic

solid. But men of science were not content with showing that the laws of dynamics could be applied to the æther; many of them endeavoured to devise models which should represent, on a large scale, the actual construction of the æther. It is difficult to know to what extent their authors supposed these models to correspond to the reality; it is probably not sufficient, however, to say that they regarded them merely as furnishing useful tools for subsequent investigations. The models were usually extremely complicated, for, from the very beginning, the æther proved somewhat recalcitrant to this attempt to represent it as an elastic solid. The most obvious objection to this representation was provided by the observed motions of the planets. It could be proved that, if there were any resistance to their motions round the sun, it must be excessively minute, and how was this to be combined with the hypothesis that they were moving with great speed through an elastic solid? The answer was found in cobbler's wax. Sir George Stokes noticed that cobbler's wax, although rigid enough to be capable of elastic vibration, is yet sufficiently plastic to permit other bodies to pass slowly through it. We have only to imagine that in the æther these qualities are much exaggerated, and the motion of the planets presents no difficulty. If no substance like cobbler's wax happened to be known it is difficult to know what satisfactory answer could be returned to the objection. Here we have

the first glimpse of the remarkable combination of qualities with which it was found necessary to dower the æther. The mathematical examination of the properties of the æther, undertaken by such men as Navier, Cauchy, Poisson, Green, was continually leading to queer and unsatisfactory results, unsatisfactory, that is, in the light of our experience of the properties of matter. Cauchy, in particular, deduced a number of remarkable physical properties which were irreconcilable with one another, although one of his theories, that of the æther considered as a kind of foam, attracted the attention of Lord Kelvin.

With the rise of Maxwell's electromagnetic theory, the elastic solid æther received less attention. Maxwell himself, in his great treatise, gives no mechanical explanation of his theory; he merely shows that an infinite number of mechanical explanations are possible. With the publication of Einstein's first principle of relativity in 1905, however, the æther began to disappear; and now, with the generalised theory of relativity, it has become a mere ghost. There are still sturdy champions of the æther, and, indeed, it seems a pity to have to abandon the mechanical explanations it promised. But possibly the attempt to find dynamical explanations of this kind is doomed to failure; perhaps, after all, nature is not flexible enough. The orientation of modern science is in another direction. It is towards a more abstract class of theories altogether—theories

which tell us nothing about the mechanism of a process, but tell us the principles the process must obey. Such theories effect a vast unification of knowledge. They are magnificently comprehensive, and it is possible that they contain all that we can really know, although men will long be reluctant to abandon all hope of ever approaching reality with the intimacy that the theory of the æther seemed to promise.

V

Whether or not it be true that the proper study of mankind is man, it is certain that he finds great difficulty in studying anything else. His first impulse, when he thinks about the universe at large, is to consider it in reference to himself, and to explain it in terms of his own actions and desires. In Astronomy, for example, it long seemed quite reasonable that in the peculiarities of men's bodies should be found the system on which the universe is constructed. The arguments of Galileo's contemporaries amuse us now, for we have learned modesty, but the tendency to explain all things in purely human terms, as it were, is by no means yet extinct, and is still a hindrance to science. It is even hinted that man's explanation of himself is not free from bias; psychologists inform us that a man's account of his own actions is not always to be trusted, that the true springs of his conduct are usually those he

would blush to own. But if we are to say that man's speculations about the universe show an overwhelming sense of his own importance we must allow him also a certain generosity. Until quite recent times he was willing to dower almost anything, animate or inanimate, with his own attributes. He credited stones with life and trees with desire, while the whole animal world were his brothers. He could admire the loving sentiments of the dove and weep for the sorrows of the crab. A pathetic confidence in man as the type and exemplar of the universe informed nearly all the early writings on animal psychology, and Descartes' theory that animals were automatic roused a sentimental indignation which has not yet subsided. Nevertheless, comparatively recent investigations tend to overthrow the natural assumption that worms and insects are little men inhabiting strange bodies. The modern biologist refuses to be conscience-stricken when referred to the industry of the bee or the conjugal perfections of the dove. It is only recently that he has become so heartless. Darwin, in a celebrated passage, describes with simple reverence the mutual affection existing between snails. The intelligence of these little creatures was also estimated highly by Romanes. Loeb, the great American biologist, did much to upset this naïve anthropomorphism. He took some worms who are "always attracted by light," and showed that this movement did not testify to a "more light" cry in these little souls,

but was a purely automatic proceeding. The worm places itself so that both sides of its body are equally illuminated. It is a mechanical action due to the influence of light on the living matter of its body. If there are two lights the worm passes between them, thus securing equal illumination of its two sides.

The crab which, being held by a claw, sheds that claw and hurries to the nearest rock for shelter, is found to do the same thing after its eyes or brain have been destroyed. Dr. Georges Bohn, who has made many experiments to determine how far the actions of the lower animals are purely mechanical, gives an interesting account of a certain parasitic worm which attaches itself to the fish called the torpedo. He finds (1) that if the amount of salt in the water be varied the reactions of the worm alter; (2) that if light be allowed to play first on one part and then on another part of the worm, its reactions alter; (3) if the animal has already taken up its position, attached to the glass, for instance, and a shadow be passed over the top of the vessel, the whole body of the worm turns itself into the vertical in such a way that if the shadow were caused by a passing torpedo, the worm could attach itself to the fish. If, however, it be already attached to a torpedo, it does not raise itself at a passing shadow. Here, then, is an *association* between the region of the body excited by light and the part fixed to the fish. It was found, also, that the crab which abandons its

claw only does so when held by a certain part. The action appears to be purely automatic. If it were dependent in any way on the crab's simultaneous visual perceptions, for instance, an associative phenomenon would be established. But experimental tests find no such correspondence. As the result of numerous experiments of this kind biologists have become very wary of offering psychical explanations of the actions of the lower animals. Even when genuine associations are established one must be careful not to interpret them in terms of human psychology. In the very description of experiments an unwarrantable turn may be given to the phenomena by the fact that words of ordinary language inevitably call up associations which may be out of place in the discussion. To say that an amœba *learns* to reject certain foreign particles in a solution, for instance, is a statement that requires careful interpretation. How are we to picture an amœba *learning* something?

But, indeed, the danger of anthropomorphic interpretations becomes very obvious when we reflect on the purely physical phenomena which accompany man's own emotions. If the James-Lange theory be correct, it is in terms of these physical phenomena that we must understand man's emotions. Now consider the example given in Washburn's book, *The Animal Mind*. An angry man has a quickened heartbeat, altered breathing, a change in muscular tension, and a

change in the blood. Consider a wasp. It has no lungs, but breathes through its tracheæ; the circulation of its blood is fundamentally different from that in man; all its muscles are attached internally because its skeleton is everywhere external. What, then, is an "angry" wasp? It seems clear that if a man is to study anything but man he must forget himself as far as possible.

ON LEARNING SCIENCE

It is a well-known fact that a really intelligent child finds great difficulty in believing that the earth is round. Stupid children, on the other hand, believe anything they are told. The difficulty experienced by the first child is due to the fact that, in however elementary a way, it is conscious of the implications of the statement. The stupid child seems to be unaware that the statement has any implications; it seems able to accept almost any statement in some curiously bare, unrelated fashion. Hermann Bahr has an interesting and amusing story of how profoundly his faith in his father was shaken when the latter, *à propos* of a sunset, told the young boy that in reality it was the earth that turned round and not the sun. Completely overwhelming objections to this staement rose instantly in young Hermann's mind, and, outraged by this insult to his intelligence, he preserved a hurt and dignified silence that lasted for days.

We notice the same essential difference in school-boys and university students, and, in fact, in men

of any age. Perhaps the majority of men, and less certainly of children, have but little sense of the implications of a statement. The sense of implications does not necessarily involve the ability to discover the implications—that is a comparatively rare gift. It acts rather in a negative manner, making the student restless under a subtly illogical presentation of a case, or leaving the schoolboy frankly mutinous at the end of a sermon. It is not a gift which makes a rapid learner, although its absence will prevent a man from ever knowing a subject properly. It is unfortunate that education, as practised in this country, does not sufficiently take into account this very desirable inhibition. The text-book plays a very large part in contemporary education, and most text-books are designed for those who can swallow statements at great speed. That delicate web of doubt, of half-seen alternative explanations, which comes into the mind of the intelligent student when confronted with the highly dogmatic statements and somewhat perfunctory " proofs " of many modern text-books, counts as sheer loss in the examination race. This is especially true of scientific text-books, which are usually conceived on an entirely wrong plan, judged from the standpoint of rational education. Statements which are the final expression of very difficult and slowly acquired abstractions are presented in all their nakedness, and followed by a collection of " examples." The glib student

learns these statements as if he were learning a foreign language, and soon masters the tricks necessary to apply them. I have known such students able to solve very difficult problems and yet entirely unable to meet, in any way, a sceptical attack upon the fundamental theorem they employ. The fact is that this method of teaching science is psychologically unnatural, and the knowledge acquired on this method is largely sham knowledge. While it may not be true that the child passes through "cultural epochs" in its mental growth, it is true that it will feel many of the hesitations and difficulties experienced by the men who first formulated the concepts now presented to it for its instant acceptance. It is for this reason that the best method of teaching a science is probably the historic method. In this way not only are many doubts fairly met instead of being merely repressed, but the exact *portée* of a statement and possible lines of extension are much more clearly seen. The effect of the modern text-book is to make the intelligent student feel that he is remarkably unintelligent; the text-book writer is so terribly cocksure.

But if the historic method must be rejected as too lengthy one may plead for its partial application. Let the text-book give the broad outlines, and let the student supplement these by reading, wherever possible, the standard memoirs written by the original discoverers. In this way he will gain something much more valuable than a more

thorough acquaintance with his subject; he will learn something of the mental gesture of the true man of science, something very different from the glittering efficiency of the text-book writer. Consider, for instance, the following passage from Newton, writing on the theory of light: He discusses a corpuscular theory, and continues:

> But they, that like not this, may suppose light any other corporeal emanation, or any impulse or motion of any other medium or æthereal spirit diffused through the main body of æther, or what else they can imagine proper for this purpose. To avoid dispute, and make this hypothesis general, let every man here take his fancy; only whatever light be, I suppose it consists of rays differing from one another in contingent circumstances, as bigness, form, or vigour.

The subject here becomes alive in a way it never does in the text-book. It is of the greatest importance that the student should see, not merely the results, but the avenues of approach. He will gain more confidence in his own powers and more interest in the subject.

For those people also who, without being students, take an interest in science, the reading of original memoirs may be recommended. Much of the science they learn in this way will be wrong, but they will see it as something thoroughly human and, it may be, as something thoroughly sympathetic. The text-book has an air of infallibility which is very repellent, and it is difficult

to avoid associating this with the scientific man. But it is merely a manifestation of the same tendency that produces stereotyped restaurants. A reading of the old memoirs shows science as tentative, imaginative, courageous. They show that the man of science is a humanist.

THE ENTENTE CORDIALE

Those who are interested in current "serious" literature, and more particularly that branch of it which deals in a speculative way with those vague but impressive problems which have always haunted men, the existence of God, the "meaning" of the Universe and so on, cannot have failed to notice the unaccustomed prestige now enjoyed by science. The supposed contributions of science to these discussions are now listened to with a gravity and politeness, with a kind of serious hush, which was formerly reserved for quotations from Plato and Aristotle. Compared with the crude materialists of Huxley's day, it is evident that the modern man of science has greatly improved his social standing; he now frequently talks to the best people, on equal terms, on such subjects as the Good and the Beautiful. The underbred, pushing, clamorous self-assertion of the Victorian scientist is a rare note in these improving conversations between philosophers and men of science. A man like Haeckel is dismissed as a mere vulgarian; no one would trouble to refute him; his loud

voice and hob-nailed boots are sufficient condemnation. Even Huxley is felt to be a rather noisy person ; the modern expositor of the relations of Science and Religion or Science and Philosophy no longer borrows his technique from the Hyde Park orator ; he has adopted rather the insinuating charm of the curate. There are, of course, survivals on both sides ; sweetness and light are not yet universal ; the general atmosphere of mutual forbearance and respect is still occasionally marred by the harsh note of some exceptionally fanatic or insensitive partisan. One or two grave lapses of this kind may be detected amongst the mass of recent books devoted to cosmical questions. There are still one or two literary men and philosophers who hint at those dreadful early days of science, before it went to Oxford, and there are still one or two provincial men of science, *farouche*, suspicious, who attend a modern cultured salon carrying their obsolete life-preserver in their pocket. But on the whole good manners prevail everywhere. It is realised that there is no reason why anybody should feel awkward at meeting anybody else in a world which is so indulgent of the difference between a man's private and public capacities.

To be on amiable terms with everybody is worth a sacrifice, and in our relief at escaping from the ferocious savagery of the Victorian controversialists we may well endure the minor discomforts of a reconciliation between science, philosophy

and religion so effective as to render indistinguishable the separate persons of this trinity. The particular advantage of this amalgamation that concerns us here is the fact that it has brought a new branch of literature into existence. As is usual in an amalgamation, each member profits by the custom brought by the others, until finally a composite article is evolved which is, as it were, simultaneously buff and blue. That is how we get these very curious and interesting modern works on cosmical questions—works which seem to result from a close collaboration between, say, a professor of physics, an archdeacon and a Bond Street crystal-gazer. A very comprehensive *Weltanschauung* is thereby afforded, and doubtless a truly "balanced" mind must result from the perusal of such works, but we may doubt whether each component, as it were, is presented in its purity. The advantages of association are only obtained by a certain loss of individuality. We cannot speak for the philosophy and religion of these works, but we are impelled to these reflections by detecting a certain quality which pervades the scientific part of the expositions. It is, as we have admitted, a good thing for science that it has been taken up in this way. It moves in an atmosphere of culture; it finds itself being described in chapters headed with Greek quotations; it is complimented on its strong vein of poetry; its peculiarities are explained, inaccurately but sympathetically, in columns of literary causerie, and

the unexpected but gratifying discovery is made that it by no means lacks the bump of reverence and proper respect for constituted authority.

Yet, kindly as are the surrounding faces, and pleasant as is the consciousness that one's clothes and accent excite no comment, there is, on the part of many scientific men, a persistent uneasy feeling that one has gained this position on false pretences. It is these remarkable modern books to which we have referred which render the feeling acute. At the same time, it is very difficult to state precisely the elements of this feeling. We understand, however, that there are young poets and novelists who experience very much the same emotion when one of the great "official" men of letters talks about literature. It appears that such people often get everything subtly wrong, that their criticism never pierces to the real heart of the matter, that they make literature at once more pompous and more tame than it really is. These new cultured expositors of science affect one very much like that. Their indisputable intelligence and their wide knowledge do not save them; they lack something—it may be a mere familiar way of talking—which marks the practitioner; we feel they touch their subject with padded fingers. We attribute no occult influence to laboratories, but we think the expositor of science who is not also a creator is something like that curiously unconvincing creature—the theoretical sailor who has never been to sea. For

that reason we are uneasy in the presence of these numerous modern expositions. Such work of the kind as was done in the old days was done by real men of science in their spare time. They had the competence, if also something of the crudity, of the workman in the factory who explains to you how his machine works. The modern writers are so much more like those frock-coated "attendants" at Exhibitions. One is oppressed with the same suavity, the same incredible readiness, the same secret doubt whether he has ever handled a tool in his life. . . .

Such being our estimate of our modern teachers, we may be permitted to be sceptical concerning the complete satisfactoriness of their account of the present disposition and relations of science. When they vouch for the complete respectability and harmlessness of science we wonder if they are not a little too kind. We have an absurd nervousness, as in the presence of a reformed burglar. He looks well-dressed enough and his hands are not impossibly horny; moreover, we are told that the two very respectable gentlemen with him find him a most charming companion. We are prejudiced, we suppose; but to our thinking there is a coarseness about the jaw, an occasional hard glint in the eye, which would make us reluctant to accept him as, at any rate, a sleeping companion. We wonder if those two gentlemen, the one reverend and the other nearly so, ever feel a little apprehensive during the night?

POPULAR SCIENCE

The Victorian Age was unquestionably the great age of physical science. It was not only the number and quality of the scientific men whose working lives were covered by this period that were responsible for this—although no period in history makes a braver show—but it was due also to the fact that the scientific discoveries of that age were often of the kind that rouses a vast amount of public attention. The attention of a cultured minority was no new thing in the history of science. Newton's discoveries, largely through the influence of his indefatigable populariser Voltaire, speedily became, in a more or less adequate form, the common property of the cultured part of Europe. But from the time of Newton to that of Davy there was no such general attention paid to science; England and the Continent largely lost touch, even technical students working in comparative isolation, so that the great French advances in Newtonian philosophy were not appreciated for several years in England, and the cultured public in England itself no longer con-

sidered the intelligent observation of scientific progress to be one of its chief duties. It never did regain this outlook; science, becoming increasingly technical, became more and more completely the affair of a small and specialised class, until, by the middle of the nineteenth century, it was the most dissociated of intellectual activities. The great recrudescence of general interest in science was brought about by the discovery that this dissociation was merely a consequence of lack of attention, and that, in fact, scientific discovery was not unconnected with the major interests of mankind.

The publication in 1859 of Darwin's *Origin of Species* persuaded the men of that time, rightly or wrongly, that science and religion were very intimately connected, and science, at one blow, obtained a degree of public attention without precedent in its history. The interest thus evoked was not always very intelligent, but it was intense and widely diffused; it extended to other branches of science, influenced the educational system of the country and gave rise to an enormous extension of "popular" science lectures and articles. This popular interest was of a different kind from the leisurely interest previously shown by the cultured classes. The latter was, indeed, much more genuinely an interest in science for its own sake; the former had a different emotional basis and was merely the diversion of an interest in religious or social questions. There is a controversial air

about nearly all the popular scientific writings of that time; the scientific man, like his audience, was fully aware that he was talking about a good deal more than the ostensible subject of discussion. Science, the creature of the least popular of man's activities, patient and unprejudiced ratiocination, became associated with violent emotions. With Biology and Geology this association was inevitable and immediate; their subject-matter happened to be that of the first few chapters of Genesis. But the more exact sciences, when public attention turned their way, could offer no such excitements. They seem to have compromised by specialising on "marvels." The "Marvels of Science" became a familiar heading, and the unsophisticated public were stunned by figures: the distances of the stars, the number of molecules in a cubic centimetre of water, the weight, in tons, of the earth, the incredible minuteness of light-waves, and so on, the whole object of such discourses being, as Maxwell unkindly put it, to prevent the audience realising that intellectual exhaustion had set in until the hour had elapsed.

We readily admit that popular science of a very different kind was also provided. Faraday, Kelvin, Huxley, Tyndall, Maxwell himself, did their best to make the lay public acquainted with scientific methods as well as results, to present their results as part of a coherent theory instead of as items in catalogue of marvels. But it is the marvel-mongers who have proved most tenacious of life,

so that "popular" science has now become a term of contempt, and any statement whatever, provided it has the right marvellous flavour, may be printed in our newspapers as scientific information. In America such marvellous statements, not only inaccurate but meaningless, occupy pages of the Sunday supplements, so that that meritorious organ, *The Scientific American*, has to announce, in self-defence, that it publishes, not "popular" science, but merely non-technical science. In our own country that sober periodical *Nature* used to print extracts from the more marvellous scientific items provided by the daily press, thus furnishing a little light relief from its own austere pages. The fact that this quackery exists is not unimportant. If it does no more, it often leads to a waste of time, for there has been more than one worthy gentleman who has imagined himself to be attacking the pernicious doctrines of science, when, as his argument makes clear, it is this kind of quackery he has in mind. The cure for this kind of thing would seem to be the development of a conscience in newspaper editors, unless we prefer to wait patiently until a tincture of science forms part of the education of an English adult.

But, turning to the popular but accurate scientific article, we may ask what purpose it serves. Should its object be to supply the deficiencies of a defective general education, to provide an easy introduction to science? Doubtless such articles

or lectures have served such a purpose ; Faraday himself, as we know, was won over to science by the blandishments of Mrs. Somerville, and there is more than one case where the current of a man's life has been definitely changed by a lantern lecture. It is, nevertheless, a mistake to suppose that the attentive perusal of a number of popular science articles is equivalent to a scientific education, a mistake which is unfortunately very common. The fact is that the scientific treatise and the popular science article, so far from being rivals, serve entirely different ends, and may be read with profit by the same man. Broadly speaking, the function of the popular science article is to present science in its humanistic aspect. It should, while dealing with as definite a scientific problem as the author chooses, hint at the relations between this problem and the other interests of mankind. Very often these relations are implicit in the subject ; such subjects are, in fact, usually chosen, and for that reason. But there is another type of article which has for its object the exposition of relations which are not obvious, and this exposition may be the result of a genuine and valuable intellectual effort on the part of the writer. Such articles are really essays in criticism and are not essentially different from the best type of literary criticism. Some of the best articles of this kind —some of those by W. K. Clifford, for example— are as truly "research" work as is the technical paper. A third type of article may, either by way

of history or by way of logic, show the position occupied by a given theory or fact in a scheme of knowledge. This type is usually of more interest to the scientific student than to the general reader, since a general acquaintance with the whole subject is presupposed, and in this connection it is interesting to note that a powerful plea has recently been made for the more effective endowment of the teaching of the history of science.

If a popular science article serves none of these three purposes, it must inevitably be nothing but the description of a "marvel." In competent hands this may be agreeable enough; the appetite for marvels is vigorous and universal, and its indulgence cannot be condemned as a vice. To look at a marvel for the pleasure of gaping is not, however, a very intelligent occupation, and, to judge from the number and kind of phenomena unhesitatingly ascribed to "the electricity in the air," merely increases credulity. Regarded as a marvel, wireless telegraphy is, of course, merely a miracle, a fact extensively exploited by spiritualists. The human tendency to seize on the merely marvellous should, in fact, be carefully allowed for by the writer of popular science articles; he should, if anything, be even more reserved and pedantically precise than when addressing a scientific audience; an incautiously flamboyant remark is very likely to be seized upon to support some preposterous philosophy or religion. Usually, however, the popular science writer yields to the temptation, to

épater his audience, to make himself more readable, as readability is now understood, and so he may, while speaking the truth, have all the effect of telling a lie.

Thus the division between the genuine and the quack science article is not, in practice, clearly defined. The difference between the writers is definite enough; but it is writer and public together which make the popular science article. Lack of education is just as great a hindrance to perception as is lack of sensitiveness. The poet may be subtly and completely misunderstood because his audience lacks sensitiveness, and, to compare small things with great, the conscientious retailer of scientific information may be in a like case for a different reason. So that if it is true that the best type of poetry is that written by the poet "for himself," it is perhaps true that the best type of popular science article is written for a similar reason—because the writer is genuinely interested in working out certain speculations or treating certain facts in a certain way. Some of the very best popular articles—those by Helmholtz, for example—are of this kind, and have achieved a relative immortality, although, like the poetry which is read chiefly by poets, they are probably read chiefly by scientific men.

PATIENT PLODDERS

It is a melancholy fact that the estimable qualities of patience and industry do not, by themselves, enable their possessor to attain eminence in the arts. There is very good reason to suppose that character, particularly a certain simple type of integrity and sincerity, is necessary to great artistic achievement, but it is certain that such gifts are not sufficient; they must be allied with very unusual mental qualities. In the sciences, however, we often find work of very great importance being performed by men of quite average intelligence, but of exceptional tenacity. A pure heart seems to be all that is necessary. This is not true, of course, of the mathematical sciences—mathematicians, like musicians, are "born"—but it is very obviously true of what are called the "observational" sciences. A history of Astronomy, in particular, is interesting from this point of view. The fact that the whole of our knowledge of the heavens comes through the sense of sight, and that we cannot experiment, in the ordinary way, upon the heavenly bodies, means that the

patient observer, by merely accumulating observations, is performing an absolutely essential function. There is no other subject which yields such rich rewards to mere patience. There is no other subject which has so long a record of valuable discoveries achieved by purely average ability. It is interesting to notice how often a telescope and a capacity for sitting still have made their owners immortal. In the region of stellar astronomy the minuteness of the phenomena which may be observed has narrowed possible competitors to those possessing large instruments, and that usually means public institutions and professional astronomers. But the history of our knowledge of the nearer heavenly bodies, the sun, the planets and the moon, owes much to the industrious amateur. No history of planetary and lunar discoveries would be complete without mention of Schröter, the "Oberamtmann" of Lilienthal, who watched the moon and planets incessantly for thirty-four years with a patience only equalled by his enthusiasm. He died of a "broken heart," the result of a French atrocity, for after firing, on the night of April 20, 1813, the Vale of Lilies and thereby destroying, amongst other things, the whole of Schröter's books and writings, the French army under Vandamme broke into and pillaged his observatory. The old man, then sixty-eight years of age, had not the means to repair the catastrophe, and, deprived of his one great interest, he died three years later, leaving, amongst his

published works, some of the most long-winded and entertaining observations in the history of astronomy.

But although Schröter is undoubtedly the most amusing of all amateur observers, he has had his prototypes in all countries. Francis Baily, the "philosopher of Newbury," is a good example of our more sober English product. We may have doubts as to what sort of chief magistrate old Schröter was, but we know that Baily took his profession of stockbroking with the utmost seriousness. He did not allow astronomy to interfere with business. Beginning in 1799, he remained on the Stock Exchange in London for twenty-four years, devoting his leisure largely to solar observations, particularly those connected with eclipses. It is with two of these phenomena, the first annular, a ring of the sun being visible round the moon, and the second total, that Baily's name is particularly associated, in each case for the vivid and accurate account he gave of what he witnessed. The first phenomenon, a ring of bright points extending round that part of the moon s circumference which has just entered on the solar disc, is merely a consequence of the lunar edge being serrated with mountains. These "Baily's beads," as they were called, were successful, however, in stimulating interest in the physical aspect of eclipses, with the result that the next total eclipse, that of 1842, was looked for with an unprecedented degree of enthusiasm. Astronomers like Airy, Otto Struve

and Arago travelled to Central or Southern Europe to observe the eclipse, and the indefatigable Mr. Baily accompanied them. He fitted up his telescope in an upper room of the University of Pavia. The result was magnificent. At the instant of totality the sun appeared decorated with a glorious *auréole,* the famous corona. It was not, of course, an unknown phenomenon, but it had never before excited so much attention. Mr. Baily, in particular, was moved to write a most eloquent description of this flaming object. He calls it splendid and astonishing, but continues: "Yet I must confess that there was at the same time something in its singular and wonderful appearance that was appalling; and I can readily imagine that uncivilised nations may occasionally have become alarmed and terrified at such an object. . . ." Besides being a specialist on eclipses, Baily was an untiring editor of star-catalogues, and he also made no fewer than 2,153 laborious experiments, on Cavendish's method, to determine the density of the earth. He was indeed a zealous worker in what Sir John Herschel called the "archæology of astronomy." He was noted for his unvarying health, undisturbed equanimity and methodical habits.

Another testimonial to the importance of such qualities in astronomical discovery is furnished by the career of Heinrich Schwabe, of Dessau. In the hope of escaping his fate as an apothecary he bought a small telescope in 1826, and began

to observe the sun, being advised to do so by a friend. He continued to observe the sun daily (weather and health permitting) for forty-three years. Every day he counted the number of spots visible on the surface of the sun. It was a simple occupation, but it led to important consequences. His immense record of sun-spot statistics showed that the increase and decrease in the number of sun-spots did not occur in a random manner, but fell into periods, maxima alternating with minima, a complete period occupying about ten years. This figure has been modified since, but the fact of sun-spot periodicity is established and is at the present time one of the most suggestive and probably far-reaching of solar phenomena. Schwabe displayed no striking quality of mind or character beyond an almost incomprehensible patience. He was buoyed up in his spot-counting, however, by the hope of discovering a planet between Mercury and the sun, and in order to distinguish between the tiny disc of the planet crossing the face of the sun and a sun-spot, he found it necessary, in virtue of his instrumental equipment, to count the spots. When he found that, as a consequence of this pastime, he was world-famous, he likened himself to Saul who, going forth to seek his father's asses, discovered a kingdom. His magnificent serenity of body and mind enabled him to attain the age of eighty-six.

Part of his mantle fell on Richard Carrington (born 1826), who built an observatory at Redhill

with the intention of devoting himself to a study of sun-spots throughout a complete cycle. He failed to finish the cycle completely, as the death of his father made it necessary for him to divert his energies to controlling a brewery. He achieved results of great importance, however. His observations were concerned with the positions and movements of the spots, and from a series of 5,290 such observations he was enabled, amongst other things, to clear up the uncertainties attending the period of rotation of the sun. Galileo, apparently not appreciating the importance of the matter, had said that the sun rotated in "about a lunar month," and a number of other observers gave figures varying from 27 to 25 days. Carrington illuminated this darkness by remarking that there is no single period of rotation for the sun. The polar regions rotate more slowly than those in the neighbourhood of the equator; the equator rotates in a little less than twenty-five days, while in latitude 50° the period is twenty-seven and a-half days. Thus the mystery was cleared up and a fresh direction given to solar investigation.

It is difficult to say whether Astronomy still offers such rewards to industry. It is probable, however, that it still yields more to character, as distinguished from ability, than any other science, and incomparably more, alas! than the arts.

THE AMATEUR ASTRONOMER

The indifference of the Englishman is, considered pragmatically, the same thing as tolerance. It bestows freedom and leaves every man, within fairly wide limits, at ease to pursue his bent. There is doubtless a relation between this English characteristic and the fact that England, above any other country, is the home of the amateur. In England, compared with the Continent, there are comparatively few men whose dominant activity is their exclusive activity. There are many fair specialists, but there are few specialised men. There are countries such as France, where the *Gemeinplatz* of intelligent men is probably larger and more richly furnished than it is in England, but it is comparatively difficult to meet the type of man who is an eminent lawyer, an authority on Eastern poisons, and a really good judge of horseflesh. Such manifestations of a national quality may sometimes appear almost grotesque, but we believe that the quality of which they are partial manifestations is the most splendid and individual characteristic of the English intellect. It is not a quality

which produces many thrice-armed specialists, but it is a quality which produces a great number of amateurs. The English amateur in the arts belongs to a family well worth consideration, but our more immediate concern is with the amateur in science.

There was a time when the scientific amateur abounded in England. In the time of Huxley and his contemporaries, as we see from their letters, amateur zoologists, botanists, and, more rarely, amateur mathematicians and physicists, were scattered all over England and occasionally had something of interest, or even of value, to report. In the days when R. A. Proctor edited *Knowledge* the country seemed to be full of reverend gentlemen who owned small observatories and home-made telescopes. This large and interesting family seems now to be making towards extinction. The increasing complexity of the various sciences, to say nothing of the variety and cost of modern apparatus, has made anything but trifling discoveries difficult to the verge of impossibility for an amateur equipment. Perhaps the amateur who has suffered least from these changes is the amateur astronomer. There is good reason for supposing that his numbers have increased. In this branch of science the English amateur has always been particularly strong, and this cannot be attributed to the official encouragement accorded astronomy in this country. There are many more amateur astronomers in England than in France,

although astronomy counts for more in France than in England, and although, since Newton, France has played the leading rôle in the history of astronomy.

The popularity of amateur astronomy in England certainly needs explanation, for it is a pursuit attended by many disappointments in so capricious a climate, and Englishmen have few opportunities of seeing a really impressive display of stars. Perhaps the Englishman is sufficient of a Northerner to be profoundly attracted by the sheer vastness and the mystery of stellar phenomena. Then the actual telescope and its accessories probably appeal to the English love of mechanism. There are few instruments more delightful in themselves than a properly mounted telescope of moderate aperture. Its adjustment affords a pleasure as refined as that given by operating a small hand printing-press, and superior to that of mending a bicycle. Every telescope has its distinctive " performance," and one can grow as enthusiastically partisan about makes of telescopes as one can about makes of motor-cars or pianos. Whether or not these be the reasons it is certain that astronomy is the science which most attracts the English amateur. The existence of the British Astronomical Association, an amateur society with some hundreds of members, is sufficient proof of this. It would perhaps be difficult to justify by the results the amount of time and money spent in amateur star-gazing, if one estimated results from the severe

standpoint of the professional astronomer. But if one adopts a broader outlook and estimates the results in rather more human terms, then there is probably no pursuit which affords more innocent pleasure and provides, in itself, a more liberal education. It is said that the vast photographic telescopes of the present day have rendered the small instrument valueless. Even Mr. Hinks, in his excellent volume *Astronomy* in the Home University Library, says that the would-be amateur would do well to hesitate before buying a small telescope, and that a measuring machine, to measure photographs taken by big instruments, would be a far better investment. This is the severely professional point of view ; it is to mistake the psychology of the amateur observer. The amateur likes to think that he might some day make a discovery, but that is only by the way. His real joy is in doing precisely what the professional cannot do, and that is to enjoy the *spectacle* of the heavens. The ordinary run of work in a big observatory is not much more exciting than work in an ordinary business office. To sit up half the night measuring photographs would conceivably add to scientific knowledge, and there are doubtless stern men who are willing to do it. These, like computers, are the martyrs of science. The average amateur will continue to prefer his present pleasant, if ineffectual, method of adding to scientific knowledge. It is to be feared that, as one result of the war, this aimable occupation will decline. A

little before the war the amateur could purchase a modest but thoroughly good, instrument at a reasonable price. The same instrument to-day would cost at least twice as much, and there would probably be an interval of several months between the order and the delivery. One large firm of optical instrument makers announces that it is not now making astronomical telescopes at all. At the present time, when astronomy is entering on perhaps the most pregnant phase in its history, and when men are more than ever attracted by anything which promises escape from the fret of daily life, this lessening of the opportunities for acquaintance with the most serene of the sciences is a minor calamity. The decline in amateur astronomy will probably have no appreciable reaction on the progress of science, but it will lead to a real, if small decrease in the intellectual pleasures and spiritual wealth of the nation.

SCIENTIFIC CITIZENS

It would be an entertaining pursuit to compile the characteristics of the man of science—usually a Professor—as he is depicted in popular fiction, on the stage, and in the writings of exasperated conservatives in religious and social matters. It would be found that these characteristics combine to give one dominant and entirely untruthful impression: the man of science is represented as being scientific on all occasions. We may ignore the inferior school that portrays him as being constantly obsessed by his work—like Dickens' learned gentleman who mistook the nature of a dark lantern—and confine our attention to the Professor who is represented, not as imbecile, but merely as homogeneous. This imaginary individual is never to be diverted from his passion for precise statement and strictly logical inference. Whether the subject be politics or the state of the weather, he brings the same preliminary scepticism, the same demands for verification, that he carries into his scientific researches. As we have said, this picture is untruthful; we think, however,

that this is an unfortunate fact, and that it is highly desirable that men of science should begin to live up to the story-teller's conception of them.

We think that, at the present stage of man's evolution, science is the one activity in which he displays himself as a truly rational creature. The reason is, of course, that success is granted on no other terms; in everything else, philosophy, theology, politics, reason is usually the handmaid to prejudice. The penalties that visit error in these fields are not so swift nor so unambiguous. The ideal of truthfulness is probably more rigorous with the scientist, *qua* scientist, than with any other kind of man. But it would appear that this dispassionate rationality is hardly won and precariously maintained. Outside his laboratory the scientist may, and usually does, show himself as simple, as kindly, as credulous, as irrational as any other man. On Bolshevism, Disestablishment, the Morality of the Public Parks, his opinions will be indistinguishable from those of any other comfortable member of the lower middle class; that is to say that opinions on all such matters are "distributed" amongst scientific men according to the same statistical rules as they are distributed amongst ordinary citizens. Outside their views on purely scientific matters there is nothing *characteristic* of men of science. The Royal Society may conceivably issue a unanimous report on some scientific matter; it would issue a unanimous report on nothing else whatever. Now on the

assumption that men of science are truly rational beings this is a very strange state of affairs. Dispassionate attempts to sift evidence, to argue correctly and to base judgments solely on the outcome of these processes could hardly result in so remarkable a multiplicity of opinions. We must assume that, for scientific men as a body, their "scientific" methods of thought function only within very narrow limits. As a distinct community they are far less coherent than, for instance, the community of artists—musicians, poets, painters. The community of artists, with the exception of a few prosperous members, exhibits a really remarkable homogeneity in matters outside art. Doubtless this homogeneity is based on feeling—unless we are prepared to admit that artists, as a whole, are more rational than are men of science—and it is probable that the scientist's difference from his fellow-citizens is more an intellectual than an emotional difference. But it is surprising that greater emotional sensitiveness should prove so much more pervasive and dominating a peculiarity than greater intellectual subtlety.

It is time that men of science assumed a greater position in the general community. If a scientific training has a tithe of the *general* educational value that is claimed for it, it is time we had some evidence of that fact. Men of science must adopt a higher ideal of personal honour. At present the man who will conduct a laboratory experi-

ment with meticulous precision and describe his results in an agony of honesty will be content to be a prejudiced observer and a slovenly and inaccurate thinker in all other matters. This is the chief reason, we are convinced, why men of science count for so little in public affairs. If the Royal Society elected its own member of Parliament, who would bother about the political opinion so expressed? What greater weight would it have than the political opinion of an equal number of moderately prosperous ordinary citizens? Does not the scientific man waggle his head just as solemnly over his morning newspaper as does any unsophisticated voter?

We plead for the development of a class consciousness on the part of the man of science. We want scientific men to regard their ideal of evidence, their conception of proof, their really admirable scientific detachment, not merely as rules making for success in their particular game, but as principles applicable to every subject that concerns a citizen. Why should a man of science be merely a Liberal or a Conservative in politics? The alternative belongs to the stage of mental development that explained the material universe by saying that its moving principle was fire, or, alternatively, water. We expect a more sober contribution to political questions from, say, a distinguished physicist, than the panacea "Shoot the miners." All the questions on which scientific men now adopt "sides" as uncritically as any

simple dupe of the daily press are amenable to scientific investigation. They can reach a solution only by the application of scientific methods, and the modern world badly needs deliverance from the method of charms and incantations by which these questions are at present treated. How long are these vital matters to remain in the hands of the witch-doctors? With scientific men content to sit in the circle and help beat the tom-toms what hope is there of real advance founded on real knowledge? The artists cannot help us; they are useful indicators of the value of the product, as it were; they look pleased or they look disgusted, and that is very helpful in showing us where we are. It is the scientific man who must show us how to go somewhere else. So we plead for the conscious formation of a community of men of science, for scientific men who are at least as pervasively and constantly scientific as a good Jesuit is Roman Catholic.

THE SCEPTIC AND THE SPIRITS

It is only youth that has the energy to be bothered with everything. There comes a time when one's mind is "made up" on all sorts of things that were once matters of inquiry; we have profited by experience; we know that some things are not worth investigating. It is one of the marvellous laws of growth that this increase in wisdom should accompany physical decay. As our teeth and hair start to fall out our judgment grows riper. The law of growth is not really as simple as this, for there are many silly old men and there are one or two wise youths. The rich, mellow, balanced period is never reached by some people: Solomon, on the other hand, was noted for his wisdom while still a young man. There is, it must be admitted, something mechanical about old men's wisdom. Truth is one, of course, so that we should expect a certain unanimity. The answers of the old can usually be predicted. Wisdom can be simulated; all that one lacks is the conviction, the spirit that animates the letter.

Deep conviction is a very impressive quality,

especially to youth, which secretly doubts everything. The man of strong convictions is a cause of optimism in others, for life would appear a sad cheat if the payment for sixty years of it did not include one certainty. Youth's certainties make as much noise, but everybody detects the bluff. A fearful man shouts to hearten himself, as all the world knows. Between the certainties of youth and age there is scepticism, a *fine fleur* of brief life, an exquisite tempering of the soul, neither too soft nor too hard, an infinite flexibility. It is a state of intense activity; life lived at this pace cannot long endure; the tired spirit relaxes and one finds rest either in credulity or in dogmatism, accident determining which attitude affords the soundest slumber. It is not always easy to detect the true sceptic; that honourable title has often been wrongly bestowed—Voltaire, for instance, was a dogmatist. Sceptics exist in all ages, but they are more clearly revealed at those periods that see the birth of some new inquiry. It is essential to their indubitable manifestation that the inquiry should be attended by the passionate interest of a large number of people. At the present day a very good test inquiry is spiritualism. It is a very much better test than Free Trade and Tariff Reform, for, owing to its comparative remoteness, the true sceptic of that alternative might live and die in obscurity. But spiritualism is a subject on which no one is genuinely indifferent and towards which hardly anyone is

genuinely sceptical. Dispassionate inquiry on this, as on all matters where human interests are strongly engaged, is usually a pretence. We need not suppose that the great ones of the Psychical Research Society are less credulous than the majority of believers or less intolerant than their louder opponents; it is merely that, their traditions being scientific, they have better manners.

Psychical literature, as a whole, is as wearisome as theological literature, as incredible but less amusing than the lives of the saints. We lack the quality, be it faith, hope or charity, which would enable us to share these strange excitements. The "exposers," on the other hand, are too sturdy in their common sense. We hear the mallet fall, but we are not always sure that the eggshell is broken. It is a situation for the sceptic. In the late Lord Rayleigh's presidential address to the Psychical Research Society we find that the sceptic has at last appeared. It is merely a record of his own experiences, very plain, very simple, and, like the experiences themselves, singularly elusive. Many years ago, in a friend's rooms at Cambridge, he witnessed an exhibition of the powers of Madame Card, the hypnotist. When she had completed her passes over the closed eyes of those present she asked them to open their eyes. "I and some others experienced no difficulty; and naturally she discarded us and developed her powers over those—about half the sitters—who had failed or found difficulty."

From hypnotism he passed to spiritualism, his interest aroused by Sir William Crookes' experiences. He induced the medium, Mrs. Jencken, and her husband, to visit his country house as guests. He describes the results as disappointing:

I do not mean that very little happened, or that what did happen was always easy to explain. But most of the happenings were trifling, and not such as to preclude the idea of trickery. One's coat-tails would be pulled, paper cutters, etc., would fly about, knocks would shake our chairs, and so on. I do not count messages, usually of no interest, which were spelt out alphabetically by raps that seemed to come from the neighbourhood of the medium's feet. Perhaps what struck us most were lights which on one or two occasions floated about. They were real enough, but rather difficult to locate, though I do not think they were ever more than six or eight feet away from us.

Another incident was the gradual tipping over of a rather heavy table at which they had been sitting. "Mrs. Jencken, as well as ourselves [i.e. Lady Rayleigh and himself. The husband was not admitted to these séances] was apparently standing quite clear of it." He found it very difficult to reproduce the phenomenon himself, using both hands. He endeavoured to "improve" the conditions for some experiments. After being shown some writing, "supposed to be spirit writing," he arranged paper and pencils inside a large glass retort, which he then hermetically sealed.

Nothing then appeared on the paper at these séances. "Possibly this was too much to expect. I may add that on recently inspecting the retort I find that the opportunity has remained neglected for forty-five years."

And so he has left the matter. The experiences were certainly strange, yes, but in his judgment, not strange enough. On the other hand, he is reluctant to believe they were due to fraud, and he is quite convinced that he was not a victim of hallucinations. If Mrs. Jencken were a clever fraud "her acting was as wonderful as her conjuring." She practically never made an intelligent remark on any occasion. "Her interests seemed to be limited to the spirits and her baby." In investigating this subject he finds that the attitude of convinced believers makes a difficulty. They "take no pains over the details of evidence on which everything depends." Others attribute all these phenomena to the devil and will have nothing to do with them. "I have sometimes pointed out that if during the long hours of séances we could keep the devil occupied in so comparatively harmless a manner we deserved well of our neighbours."

The general disbelief in scientific circles that meteorites really came from outer space occurs to him. This disbelief was due, he points out, to the impossibility of producing the phenomena at pleasure in our laboratories. Nevertheless, the disbelief was unjustified. Spirit manifesta-

tions may be, he thinks, just such sporadic phenomena. The situation is made worse by the fact that there has undoubtedly been a great deal of fraud in connection with spiritualist phenomena. Eusapia Palladino, for instance, undoubtedly practised deception, " but that is not the last word." Telepathy puzzles him. If there is such a means of communication, why should Nature have adopted the laborious method of building up our very complicated senses ? An antelope in danger from a lion, for instance, depends on his senses and speed. " But would it not be simpler if he could know something telepathically of the lion's intention, even if it were no more than vague apprehension warning him to be on the move ? " He advises the society to continue their investigations, and mentions that it is quality, not quantity, that is so desirable in evidence. He concludes by saying that he fears his attitude, or want of attitude, will be disappointing to some members of the society. He suggests that after forty-five years of hesitation " it may require some personal experience of a compelling kind to break the crust." He apologises for this. " Some of those who know me best think that I ought to be more convinced than I am. Perhaps they are right."

There he leaves us. We do not believe more or disbelieve less, yet we are completely satisfied. His massive sincerity, his obvious competence and, above all, that impression of exquisite

balance, have charmed us. So far as present evidence is concerned we feel that while he has said nothing he has also said the last word. That is the function of the sceptic.

THE SCIENTIFIC MIND

It is quite common, in reading and in conversation, to find references to the "scientific mind," but it is difficult to ascertain precisely how this mental structure is supposed to differ from other sorts of mind. The difficulty of defining an object does not, perhaps, affect the probability of the existence of the object; although it is difficult for some people to refrain from concluding that because a man cannot define what he means he does not mean anything. We must suppose that there is some particular kind of mind called the scientific mind, in spite of the fact that the numerous references to it tell us little about it except that it is somewhat extensively disliked. So far as can be judged from a superficial comparison of different references, the "scientific mind" is characterised by an inordinate appetite for facts and an absence of generosity in drawing conclusions from facts. In ordinary times this absence of generosity is dismissed by most people as quibbling, while in time of war it becomes unpatriotic. During the war every Englishman

was supposed to believe a great number of things on very slender evidence or even on no evidence. It was considered that a right patriotic feeling not only could, but should, supply the place of evidence, and lead to correct conclusions. The majority of people in every class of the community found themselves able to adopt this method of thought without discomfort, and it became evident that the scientific mind is as rare amongst scientific men as amongst any other men, while those who could not give this supreme proof of patriotism were found pretty evenly distributed amongst the different classes. As a type of mind, therefore, it is not peculiar to scientific men nor do they all possess it. It cannot be regarded as a distinguishing mark of this class. But while a just, cautious temperament need not belong to the man of science as a human being, it might be thought that, as a mental habit, it is necessary to his work. There is much truth in this, although it is not wholly true. Alternative explanations are not always explored by scientists, and if, as sometimes happens, the alternative explanations are wrong, the scientific man may have reached a correct result although he worked in a partisan spirit.

But while the characteristics of what is popularly known as the scientific mind are not peculiar to scientific men, it is true that, in their actual scientific work, these characteristics have a greater survival value than they possess in almost any

other kind of work. The extent to which mental habits may be local, confined to some only of a man's mental activities, has been made apparent by the war. The majority of men's minds are split up into water-tight compartments in a way truly astonishing, and the various eloquent addresses on the moral value of scientific studies now make melancholy reading. We must assume of scientific men, as of any other class, that such qualities of fairness and deliberation as they exhibit in their work are imposed upon them as conditions of success, and are not, in general, the natural manifestations of an exceptionally delicate moral sensibility. If we adopt William James' classification of human beings into tender-minded and tough-minded the dividing line runs through the scientific camp as through any other. We see this most clearly in the case of mathematicians, for idealist or empiricist assumptions seem to be equally reconcilable with the results. Such sciences as physics and chemistry seem, at first glance, to be given over to the tough-minded ; the official language, as it were, is the language of the tough-minded, but directly controversy arises on a point having philosophical bearings we see the dichotomy establish itself.

Nevertheless, it remains true that while scientific men, as human beings, are of all sorts, they do exhibit, in their own work, a degree of mental honesty which is unusual. It is easy to see that this virtue, at any rate, has a strictly utilitarian

basis. A scientific man is honest because he cannot succeed on any other terms in the long run. The experimental verification always looms ahead. He cannot, like the mystic who maintains his opinion in face of the world, take refuge in the deeper insight. His results are communicable and verifiable or they are not science. Philosophies may be constructed which no man can verify and no man can refute. Their authors may, with complete assurance, remain satisfied of their truth and lament the universal blindness of mankind, just as a poet may present a front of unconquerable self-esteem to the ignorant derision of the world. But the whole claim of science is that it is communicable and capable of verification. It is found, as a matter of experience, that results of this kind are not usually obtained unless a certain mental habit is first acquired. It is this mental habit which is usually called the scientific mind. Where it is the outcome of a natural predisposition it may be classed as a moral quality, and, as such, is not peculiar to, or widely distributed amongst, scientific men. But as a tool, as a kind of technique, it is of more obvious value and is more extensively employed in the sciences than in any other human activities.

THE SCIENTIFIC CONTRIBUTION

For something like seventy years science has been the dominant intellectual activity of the Western world. During that period the range of its material has greatly increased until now the scientific method is regarded as the method proper to almost any investigation. Philosophy is still a partial exception, but there is a strong tendency to regard such philosophic problems as are not susceptible to the application of the scientific method as being essentially incapable of solution, or else as incorrectly stated. But although the prestige of science is so great, and the general attitude towards it so reverential, there is still much confusion respecting its function and achievement. Its relations to other human interests and activities are not yet clearly defined. The attempts to define them by allotting to science its "sphere" have proved, in the result, to be so ill-judged that it is now considered safer to waive the question of limitations altogether. The question is not settled. Everything is left open, but it is not therefore assumed that science contains or will contain all

we know or all we need to know. Science is not yet the one object of our contemplation: we have a number of interests which still lead separate lives. The separation is not complete. Science, if not openly, then indirectly, has invaded every province of the mind, and even a modern musical composition counts Copernicus as well as Beethoven amongst its ancestors. But it is admitted, of course, that we are not usually reminded of astronomy in listening to music; there is a sense in which music, and many other things, are autonomous. But it is interesting to notice that science, to a greater extent than any other pursuit, can be isolated, although its historical direction has been influenced, of course, by social and political accidents. Science has given generously, but has taken comparatively little, and its few borrowings are in process of being handed back with regret as being, after all, unsuitable.

What, then, is the precise nature and extent of the contribution of science to our total stock? Although we do not intend its practical applications by this question, we cannot wholly ignore them. It is impossible completely to separate the "material" and "spiritual" aspects of life, and the sum of the practical applications of science has even profoundly affected much of our abstract thinking. Where it has not originated questions it has at least made them acute, if by no other process than by creating or transforming social conditions. It is easy to trace the ancestry of

whole schools of social philosophy to the steam engine and the dynamo, and it is probable that the influence of future applications will be even more extensive. The morality, art and philosophy of, for example, a disease-less world, where the average span of human life was two or three times its present value, would certainly differ greatly from our own. We cannot, then, ignore the practical applications of science, although they are not, in themselves, pertinent to our question. But when we turn to consider the direct spiritual value of science we are conscious, at the outset, of some hesitation.

It was a common article of the Victorian scientist's creed that scientific study was, in itself, an " ennobling " and purifying influence. He stressed the complete detachment required, in scientific research, from all prepossessions; the man of science was completely candid, completely docile in face of the facts. Until one became as a little child it was no use entering a laboratory. We have realised since then that scientific men are human, and have their full share of the unfortunate characteristics proper to that state. But it remains true that the scientific ideal of detachment and the scientific ideal of evidence are higher than the corresponding ideals elsewhere. In spite of the evidence furnished by our newspapers we may, if we are optimists, believe that science is gradually infecting the whole community with its conception of these ideals. If this is indeed the case it must

be counted a direct and very important moral gain, as an indisputably valuable contribution which may be set over against those somewhat ambiguous practical applications.

A third contribution is to be found in the large store of æsthetic objects provided by science. Many of its theories are objects of surpassing beauty. This is particularly true of the mathematical sciences—indeed, there are a number of mathematicians who have felt impelled to write of their science in a kind of prose-poetry—but it is almost equally true of such a science as Geology. We can contemplate schemes which, in their own way, are as all-embracing as that of the *Divina Commedia*, and it does not detract from their æsthetic charm to know that they are also true. The processes by which the theories are obtained are often as æsthetically important as the theories themselves. A subtle, elaborate and economical piece of reasoning often affords great æsthetic pleasure, none the less real because comparatively few people enjoy it. The fact that the history of a big scientific investigation, such as the Electromagnetic Theory or Einstein's Theory of Relativity, is not generally regarded as a poem is due merely to an accident of language and education. But we have to admit that most people are affected by these accidents, and that the æsthetic objects provided by science count almost as few admirers as do the "beauties" of chess. If we may judge from the number of popular books and articles dealing with

science, there is some hope, however, that this particular contribution is receiving more attention. The results of such increased attention will not be simple, but if it did no more than add fresh æsthetic objects, the contribution would be important.

The fourth contribution of science, both in itself and for its reaction on other interests, is perhaps the most important of all. This contribution is, put briefly, the light thrown by science on man's place in the universe. Every branch of science conspires directly to this end. With some the emphasis is on the universe as distinct from man; others are concerned chiefly with man himself. To the general mind the result has been to make the universe bigger and man smaller, and this is, perhaps, no unfair summary. It is probably difficult, after hearing a duet sung by an astronomer and a psycho-analyst, not to feel depressed. But, such as it is, there can be no doubt that any conception of man's destiny that is to command attention must conceive that destiny as played against the background of the scientific cosmos. Whether the vision be that of a prophet, philosopher or poet, it must accept those postulates. The cosmos revealed by science, both in its direct influence upon the mind and in its almost equally direct influence upon religion, philosophy and the arts, is the most important part of the scientific contribution to our spiritual life. So far as philosophers and artists are concerned, this influence is recognised. It is probably desirable

that the influence upon philosophy should increase, but in the case of the artist we are faced with a special problem. Its discussion would be interesting, the more so in view of the fact that artists themselves have contributed very little that is helpful to its elucidation. We think it essential to its solution to remember that the artist, like the scientist, starts with facts. But the system within which the facts are related is entirely different in the two cases. The scientific scheme must, of course, be accepted by the artist *en bloc* if his work is to be more than a pure fantasy. But this is very different from identifying his own scheme with the scientific scheme. That is to fail signally to perceive the limitations of the scientific contribution. An interesting particular case of this problem is to be found in the question of the right relations of the psychological novelist to the science of pyscho-analysis. A scientific investigation is often, as we have said, a work of art, but not necessarily a work of literary art. The scientific contribution is very considerable, but offerings from the older benefactors are still gratefully received.

THEORIES AND PERSONALITIES

That a scientific theory is, in some sense, a personal achievement, becomes evident when we study a number of theories lying within the same branch of science. The ordinary belief that science is completely impersonal is certainly not true. And yet it is not easy to see how a scientific theory can express the personality of its author; it is difficult, that is to say, to understand in what way a scientific theory can resemble a work of art. It seems that the fact that a scientific theory must have "objective truth" renders it an altogether different thing from a work of art. It would be more just to say that the element of objective truth radically differentiates a scientific theory from those works of art which are independent of all experience of life—as certain musical compositions may be, for instance. But it is not clear that, in general, works of art are independent of objective truth; all those works of art which assume experience claim assent—they do, in their intention, claim universal assent—to the truth of their assumptions. The serious artist believes his

personal vision to be true ; he will not, probably, claim "absolute" truth for it, but neither does a scientific theory profess to be absolutely true. And, further, works of art and scientific theories exist to serve the same purpose—to aid *comprehension.* An artist's chief title to consideration is to be found in the depth and extent of his vision, in the profundity and range, that is to say, of the comprehension he makes possible. The value of a scientific theory is judged by the same criteria. So far, therefore, it would appear that the chief difference between a work of art and a scientific theory is to be found in their subject-matter. It cannot even be said that the subject-matter is arranged to serve different ends in the two cases, for in each case the end which is aimed at is æsthetic satisfaction. Comprehension is one of the elements of what is loosely termed the æsthetic emotion, and it is the most important element. Even when we descend to particulars, and study the quality of similes in poetry, and, indeed, "ornamentation" generally, we shall find the criterion we employ is still the degree of comprehension afforded by the device. But we cannot here work out the analogy in detail. It is sufficient to show that works of art that have a reference to experience, to an external world, in short, are, in important respects, similar to scientific theories.

Since, then, a work of art, although conditioned by experience, may nevertheless be a personal

achievement, we need have no *a priori* objection to conceding personality to a scientific theory. In each case it is the method of transformation from what we may call the raw material to the finished product which is the personal thing. The artist's raw material, whether it be the Thames in a fog, a number of incidents from Holinshed, or the lives of the inhabitants of a Russian village, is no more and no less common property than are the *données* from which a scientific man constructs a theory ; the end product, also, in each case, claims universal assent and bestows comprehension. What is personal is the law of transformation by which the one objective thing is changed into the other objective thing. The law of transformation is different for each individual mind, and this is as true of scientific men as of any other sort of men. In this sense, then, both works of art and scientific theories are personal achievements. A history of science written from this point of view would be instructive. It would be interesting to trace the personal element in each great scientific achievement, to show what kinds of personalities have dominated us, to see what meaning *eccentricity* can have as applied to the thought of a scientific man. But although a detailed history of this kind has not yet been written, certain *national* differences have long been recognised.

There is almost as marked a difference between English and French science as between English

and French literature. The English scientific mind is, on the whole, intuitive, mobile, illogical, and very prone to imagery of a curiously practical kind. The French scientific mind, on the other hand, likes to simplify the complicated reality to as few terms as possible, and then to build up an impeccable logical edifice. Maxwell was a very fine type of the great English man of science, but we have Poincaré's authority for saying that the great *Treatise on Electricity and Magnetism* awakens in the French reader feelings of distrust. So far from finding an impeccable logical structure, he finds that different parts of the book are written from different points of view, and that these points of view are even irreconcilable with one another. Maxwell's liking for immensely complicated mechanical models, designed to illustrate some abstruse equation, is also a stumbling-block to the French reader. What are such models supposed to prove? Surely Maxwell did not suppose that the æther contained trains of geared wheels with "idle wheels" in between? What mysterious satisfaction did he derive from such unnecessary and irrelevant pictures? But this curious liking for models is characteristic of the English school, and it is a characteristic that Continental physicists have never been able to understand. It is doubtless a manifestation of the English reluctance to get out of touch with experience. The English man of science trusts logic much less than he trusts experience. The Frenchman has much less respect

for experience. He is willing to simplify in a way which, to the English mind, is almost outrageous—to see the Universe as a collection of little billiard balls with forces varying inversely as the square of the distance. And on such assumptions he is willing to proceed as far as logic can take him. There is, indeed, a school in France which asserts that all we can ever know of the Universe is its equations; we can never know what they "mean" in the English sense. From the æsthetic point of view there is no doubt that the French method is to be preferred. We can all share Lagrange's satisfaction when he says, in the Avertissement to his *Mécanique Analytique*: "Je me suis proposé de reduire la théorie de cette Science, et l'art de résoudre les problêmes qui s'y rapportent, à des formules générales, dont le simple développement donne toutes les équations nécessaires pour la solution de chaque problème." But we must remember that when the interest is chiefly in the "développement" the assumptions may remain uncriticised. The English way is to hold the assumptions tentatively, and to be always open to the suggestions of experience. The German way, which, if we are to judge by the work of Riemann and Einstein, seems to be to concentrate an immense critical apparatus on the assumptions, is equally interesting. The "philosophic" tendency which is supposed to characterise German thought in other departments, is certainly apparent in its science. The three tendencies are sufficiently

marked to constitute national differences and suggest that a detailed analysis of individual achievements would yield equally interesting results.

THE IDEAL SCIENTIFIC MAN

Is the scientific man really a distinct kind of man, or is it merely that science is a distinct occupation? To answer the question we must make the elementary distinction between the scientific man and the man who practises science, and when we do that the answer is obvious. There is as certainly the "born" scientific man as there is the born artist. But in saying this we are referring to ideals. Perhaps there has never been a perfect man of science, and perhaps there has never been a perfect artist. But in order to understand the distinction between one kind of man and another it is helpful to construct ideals—extreme cases which may be used as measuring rods. What, then, are the characteristics of the ideal man of science? We may approach the solution by trying to make precise the characteristics which have led us, vaguely, to construct the hierarchy we already possess. We *feel*, for instance, that Henry Cavendish, that passionless recluse, was a much more "purely scientific" man than, say, Thomas Henry Huxley. If we examine this conviction of ours we make the

interesting discovery that it is chiefly for his negative characteristics that we assign this greater purity to Cavendish. Huxley was passionately interested in the questions which concern every good citizen, in politics, in social reform, in religion; he took sides on these questions and fought for his side. Of Cavendish we can only say that it is inconceivable that he would have taken sides on these questions, and very difficult to believe that he was even remotely interested in them. Take another point. Huxley abounded in ordinary human affections. He was a devoted husband, a good father, a faithful friend, a resolute opponent. Cavendish never manifested a vestige of any of these qualities. He had no wife, no children, no friends, and never showed the faintest dislike of anybody. Huxley was a champion of what he thought the truth, and strained every nerve to enable it to prevail. Cavendish, who was one of the greatest investigators, one of the clearest and most subtle minds, in the history of science, kept his discoveries to himself. For years Huxley bore the brunt of the attacks on Darwin's theory. Cavendish blandly watched the growth in popularity of theories he had privately demonstrated to be wrong, and never stirred a finger to rebut them. And finally, Huxley was a man who suffered his alternations of high spirits and despondency, hope and despair, while Cavendish, from the evidence we have, was imperturbably serene.

Now, the interesting point that emerges from this

comparison is that Cavendish, in virtue of his scientific purity, *could not* have exhibited those qualities which allied Huxley to the ordinary run of men. A man's characteristics are not disconnected. Cavendish's cold passion for knowledge required for its gratification qualities of the spirit as well as of the mind. No man was ever more single in his desire to *know*; no man ever was so little hindered by having other interests to serve; no man, therefore, had a greater measure of the purely scientific spirit. This is the important point for our question; it is comparatively irrelevant that very few men have ever had so great a mind to place at the service of their passion. That his actual scientific standing should be so much greater than Huxley's is an accident; he would still have been more purely scientific than Huxley had his ability been less than Huxley's. Cavendish is all of a piece. His very perfection as a recording and measuring instrument tended to deprive him of "personality." The less personal he was, in fact, the more dispassionately open he could be. Other passions were incompatible with his perfection; they would derange this exquisite instrument. Judgments of good and evil would not have been natural to him. His reaction to anything was exhausted in the act of *understanding* that thing.

So far as we have gone, it would seem that Nietzsche's description of what he calls the "objective man" is exactly what we mean by the ideal

man of science. "The objective man is in truth a mirror: accustomed to prostration before everything that wants to be known, with such desires only as knowing or 'reflecting' implies . . ." he will regard such personality as he has, Nietzsche goes on to say, as accidental and arbitrary. He cannot take himself seriously and devote time to himself. His love is constrained, his hate artificial. He is only genuine so far as he can be objective; he is unable to say either "Yea" or "Nay" to life; he is concerned solely to understand, to "reflect." He says, with Leibniz: "Je ne méprise presque rien." This description is undoubtedly the result of genuine psychological insight. When we try to disentangle the purely scientific element in a man of science we find that, so far as he is scientific, he approximates to Nietzsche's objective man. If this, then, is the ideal scientific man, what place does he occupy? Where does he stand in relation to the rest of mankind? According to Nietzsche he is merely an instrument; "he is an instrument, something of a slave, though certainly the sublimest sort of slave, but nothing in himself." He is no goal, no termination, no complementary man in whom the rest of creation justifies itself. As compared with the *true* philosopher, the philosopher in Nietzsche's sense, the man who gives a new direction to life, the ideal man of science is merely the most costly, the most easily tarnished, the most exquisite of instruments.

We need not quarrel with this valuation, but we

would point out that there is an omission in it. The scientific man is an instrument, but he is an indispensable instrument. The human race has endured all the different "new directions" given to it by the "true" philosophers of the past without any marked increase in its spiritual stature. The philosopher, however commanding, who would really lead us in any but a circular direction must have *knowledge*. This knowledge, to be valuable, must be clear and trustworthy; it must be scientific. And if the inspirations and impulses of our leaders should prove to be incompatible with deductions from scientific knowledge, then we may be sure that the Promised Land does not lie their way. The scientific man is merely an instrument. But it is this instrument alone that can show to mankind which, of all the goals it desires, are possible goals, and which, of all the leaders it trusts, are trustworthy leaders. The scientific man is an instrument, but it is by this instrument that those who would use it are first tested. Scientific knowledge is, if you like, as dispassionate and inhuman as is the universe with which it concerns itself—and it can as little be ignored.

PARALLEL STRAIGHT LINES

Geometry, it has been satisfactorily shown, had a purely empirical origin. It appears that the earliest geometrical formulæ which have been discovered belong to ancient Egypt, and that all these formulæ served a useful purpose. The oldest of them are concerned with the measurements of areas, a class of problem which the yearly sinking of the Nile rendered of great importance. The formulæ obtained by the ancient Egyptians were usually wrong, although they were approximately correct ; they evidently rested on no theoretical basis, but were compendious statements of the results of somewhat rough measurements, a point of view which is borne out by the fact that no proof, nor even an attempt at a proof, is anywhere hinted at. So far as the evidence goes, it seems to be established that geometry, as consisting of logical deductions from stated premises, began with the Greeks. A number of theorems of a fair degree of complexity had been developed before they were reduced to a system ; before, that is, the assumptions on which they were based were made explicit.

The task of discovering the necessary and sufficient assumptions on which a system of geometry rests is one of the greatest difficulty; the necessary combination of subtlety and rigour is rare. The great systematisation of Greek geometry was effected, of course, by Euclid, and although his reduction of the system to its essential assumptions was not final, his performance was such as to awaken the admiration of great mathematicians in every succeeding century. But there is one point in which this great reduction is notably imperfect—the so-called parallel axiom. It says, essentially, that through a given point only one line can be drawn parallel to a given straight line. It was felt, even by the earliest commentators on Euclid, that this postulate did not possess quite the same degree of self-evidence as was manifested by the others. It was necessary, they felt, to give a proof of this postulate; they attempted to improve on Euclid's work in a number of minor ways, but it was the parallel axiom which they were most concerned to revise; the proof of this postulate should be contained, they thought, in the other postulates. The attempts to supply this proof were all fruitless, and the sixth century was reached with this nine-hundred-years-old disfigurement still persisting. For some time after the sixth century the world rested from Euclid's parallel axiom; indeed, it rested from geometry altogether, and the old empirical outlook of the Egyptians, and even their formulæ, again became current. But the Greek

culture penetrated to the Arabs, and with the Greek culture came the riddle of Euclid's axiom. Again proofs were attempted ; a famous attempt is that of Nasir Eddin, who flourished in the thirteenth century. In 1663 John Wallis made the important discovery that unless the parallel axiom be assumed, similar figures of different sizes are not possible, that is to say, that if we are to assume that *shape* is independent of *size*, then we must assume Euclid's parallel axiom. Many of these attempts brought out points of interest, but none of them were successful. In the year 1733, however, the whole research took on a new complexion with the publication of Girolamo Saccheri's *Euclides ab omni naevo vindicatus*. The importance of this work consists in the fact that, although it was written to vindicate Euclid's parallel axiom once for all, it contains the first real outline of a non-Euclidean geometry.

Saccheri was a Jesuit, and it was in 1690, while he was teaching grammar in Milan, that he first studied the *Elements* of Euclid. He was a man of very great acumen, and when he, in turn, succumbed to the spell of the parallel postulate, he brought to bear on it a more subtle and rigorous logic than had yet been applied to it. Thirty-six years before he published his treatise on Euclid he had published a book on logic which gives him a high place as a logician. In it he is particularly concerned with investigating the compatibility of different assumptions or postulates. His method

was to determine whether a member of a group of postulates is independent of the others by finding a particular case in which the postulate in question is not true while all the others remain true. If such a case can be found, it is obvious that the postulate in question cannot be deduced from the others, else it would be true whenever they were true. This was the method he applied to the parallel postulate of Euclid. He showed that the parallel postulate is equivalent to saying that the three interior angles of a triangle are equal to two right angles. He proceeds, therefore, in accordance with his method, to develop the consequences of supposing them less than, or greater than, two right angles. In the latter case he succeeds in showing that we are led to impossible conclusions, since he assumed, as everybody assumed for more than a century after, that the straight line is of infinite length. But in the former case, the hypothesis that the interior angles of a triangle are together less than two right angles, Saccheri, although he struggled very hard, did not succeed in falling into contradictions. He does not seem to have had the boldness necessary completely to trust his own logic, but the fact remains that, accepting the rest of Euclid's axioms and denying the parallel axiom, he developed a logically consistent geometry.

There is reason to suppose that Saccheri's work had some influence on subsequent thought, although its full significance was certainly not perceived.

The parallel axiom continued to be investigated, and the total effect of all these efforts was to induce a doubt concerning the absolute *necessity* of the Euclidean geometry. Such a doubt was very daring; for two thousand years the postulates of Euclid had been accepted as absolutely true; the fact of their existence had profoundly influenced philosophy, and, indeed, theology. But the doubt persisted and grew, until finally, early in the nineteenth century, a perfectly logical and consistent non-Euclidean geometry, one explicitly denying the parallel postulate, was published to the world. As so often happens, the great step was taken by two men independently of one another, Lobatschewski, a Russian, and Bolyai, a Hungarian. It appeared, however, that both had been preceded by that great mathematical genius, Gauss, although he had been too timid to publish his conclusions. The new geometry developed the consequences of that one of Saccheri's alternatives which supposed the interior angles of a triangle to be less than two right angles. The whole outlook on geometry now assumed a new complexion. Riemann tried the effect of denying the infinity of the straight line and of developing Saccheri's other alternative. He found he was led to no contradictions. But with Riemann's work we come to a yet further extension of geometry—the extension to space of four, five, or any number of dimensions. And these investigations, which seemed for some time to constitute the most gratuitous, although

the most profound and subtle, exercises of the mind, have now received their complete justification by flowering into the Generalised Principle of Relativity.

THE NEW SCIENTIFIC HORIZON

About current scientific speculations there is one characteristic, subtle, perhaps, but profound and far-reaching, which distinguishes them from the scientific speculations of the Victorian age. We can best isolate this characteristic by considering it as a particular manifestation of something which is met with in nearly every phase of contemporary life—something which may fairly be called the *Zeitgeist* of our time. This spirit is chiefly a sense of unlimited possibilities, a sense that the radically new and unprecedented may be upon us; with this feeling comes a recrudescence of the spirit of adventure; there are unknown paths leading to vague but—probably—splendid goals. In the Victorian age the main lines of everything were settled; the chief features of the universe were known. There were matter and energy, and there was, of course, the æther. The astronomical and geological scales were known in broad outline, and a first survey of the march from amœba to man had been taken. The work of future ages was to fill in the details. The universe of the

Victorians was a large and rather grand affair, but it was sombre. Those emotional barometers, the poets, in so far as they were aware of the scientific outlook, either "transcended" it or were crushed by it. Jules Laforge furnishes an excellent example of the effect of the Victorian scientific outlook on an intelligent and sensitive mind. His reaction was to compose funereal dirges on the death of the earth and the extinction of mankind. The universe of the Victorians was objective, indifferent, tracing a purposeless pattern in obedience to "iron" laws. It was a universe which held no great surprises.

It is obvious that a very different spirit is abroad to-day. At the present time the general consciousness seems to hold that almost anything is possible. In part this may be accounted for, as in other ages, by credulity based on ignorance, but there is also a credulity based on knowledge, and it is this aspect of the general attitude which deserves attention. The two kinds of credulity may be observed in different believers of the same statements. Spiritualism, for instance, has its followers amongst those who are unfamiliar with investigations in the subject and amongst those whose belief has been compelled by their very knowledge of the investigations. And disbelievers form two exactly similar classes. There is also a credulity—the most common kind—based on neither ignorance nor knowledge, but on partial knowledge. Thus knowledge, but incomplete knowledge, of such pheno-

mena as wireless telegraphy or telephony, seems to predispose many people to believe " wonders " which have no real connection with those phenomena, but which are merely as inexplicable by partial knowledge. Undoubtedly the recent developments in science are responsible for much of this kind of credulity. But the new indulgence of possibilities, as exhibited by the man of science, is dependent on quite different considerations. To the student of physics, at any rate, the work of the last two or three decades has been peculiarly disturbing. He has been called upon, not merely to revise and extend his knowledge, but to alter his assumptions. It is in this respect that the physics of our own day chiefly differs from Victorian physics.

The distinctively modern epoch began with the promulgation of the Electron Theory. That " matter " could be " electrified " was easily granted. The fact that the famous question, What is electricity? could not be answered was no difficulty in admitting the fact that, as a result of certain processes, matter could be made to exhibit certain phenomena which could conveniently be referred to the fact that it possessed an " electric charge." And the discovery of particles very much smaller than a hydrogen atom presented no conceptual difficulties. The fact that the ultimate particles of matter were smaller than had been supposed could easily be granted; the new assumption was of the same kind as the old one. And,

further, to admit that each of these particles possessed an electric charge made no unfamiliar demands on the imagination. But the next step, that these particles consisted of nothing but an electric charge—that was a very different thing. The early popularisations of the idea show something of the mental confusion it caused. "Disembodied charges of electricity" was a favourite descriptive phrase; many physicists fought hard to retain even a nucleus of "ordinary matter" on which this charge could be supposed to be lodged. That an electric charge could exist apart from matter seemed to many people as difficult to conceive as motion without anything which moved. But the conception speedily became familiar; that useful entity, the æther, soon made things easier. For the disembodied charge, the electron, could be conceived as a local distortion of some kind in the æther, and, by endowing the æther with some sort of substantiality, the hypothesis that matter was in some way built up out of this primitive substance could be tolerated. But the general effect of the theory was to give a more philosophical tinge to science. The gross, easy assumptions of everyday thinking about "matter" had to be revised; articles were written showing that matter was really immaterial, and materialism was conjectured to have received a severe set-back.

The mind had barely become accustomed to the new assumptions before it was again profoundly disturbed by the publication of Planck's Quantum

Theory. The theory, which was invented to explain certain radiation phenomena, asserted, briefly, that energy was atomic. One's most intimate assumptions were disturbed. Men of science are not usually accustomed to philosophic exercises, and the idea that energy, which they regarded as necessarily continuous, had an atomic structure seemed at first almost meaningless. If we consider, for instance, the energy possessed by a moving body, it seems natural to suppose that this energy can be increased or diminished in a continuous manner; the idea that its energy can only increase or decrease by finite jumps was a very strange idea, and led again to a scrutiny of assumptions which had appeared fundamental in science. Here, again, objections to the new theory were sometimes the outcome purely of mental inertia, of an inability to examine and discard a way of thinking which seemed almost a necessary consequence of the structure of the mind. The last great *bouleversement* of one's fundamental assumptions has been, of course, Einstein's generalised theory of relativity. Here we are asked to revise our most deep-rooted assumptions—so deep-rooted that we are, for the most part, unconscious of them—our assumptions regarding space and time.

It is this thorough overhauling of primary assumptions which distinguishes the modern progress in physics from all the progress of the Victorian age. Physics has not merely been extended, it has become a radically new thing,

and there are very good reasons for supposing that it is going to change still more. A certain sense of unknown possibilities is therefore natural, even if it be the product merely of bewilderment. The total effect of the new ideas is to make the universe of physics less objective ; to an unsuspected extent this indifferent universe, with its iron laws, is a product of our own minds. To some extent this fact was always recognised, particularly by the Continental physicists, but as a general persuasion it is comparatively recent. We cannot escape the structure of our own minds, it is true, but we do not yet know what that structure is ; we do not know what barriers are breakable ; we do not know what thoughts are thinkable by man. A universe in whose construction so plastic and mysterious an entity as the mind of man collaborates, may very well hold great surprises.

THE HOPE OF SCIENCE

It is not an unfair judgment, we think, that decides, on a survey of contemporary intellectual activities, to grant science the first place. Whether we consider the quality of the work which is being done, its importance to mankind, or the spirit in which the work is done, we think science earns that place. Our age is a scientific age to an extent which is certainly not generally realised. Contemporary scientific work is of a quality fully comparable with that of the greatest periods of its history; it is inevitable that our age should emerge, in the history of the future, as an age of science. It has, indeed, already established a perspective which leads to a revaluation of the Victorian age. There have already been many writers who have thought that age more memorable for its science than for its other achievements, that its significance to humanity lay more in the work of Darwin, Faraday, and Maxwell than in that of Tennyson and Matthew Arnold, or even in that of Mr. Gladstone, but the perspective we have now obtained puts the matter almost beyond doubt. With most of us our out-

look is the result of a decrepit tradition. Our orientation towards life, so far as we are conscious of having one, is based upon the values we attribute to the various objects of our thoughts, and these values are determined partly by our instinctive desires and partly by the suggestions of our education—using the term "education" to include all converse with the minds of our fellows. Education, so defined, is the result very largely of a long and widespread tradition, a general tradition of European culture. It is a curious fact that, although the history of science goes as far back as the history of the arts, science is not an integral part of this, nevertheless, very catholic culture. There are periods, it is true, when some scientific theory is sufficiently dramatic, or appears sufficiently pertinent to man's destiny, to secure general attention; Newton's theory of gravitation, Darwin's theory of evolution, and Einstein's theory of relativity have each given rise to such a period. Einstein's theory, we are informed, is now the favourite topic of enlightened conversation in Parisian salons, as Newton's theory once was. Some of this interest, no doubt, is the product of disinterested curiosity, and in that respect is vastly different from the once general interest in Darwin's theory. But we fear that many of those who are curious about Einstein's theory would, if they understood it, find it uninteresting. We dare not interpret this curiosity as a sign that people are beginning to be as naturally inter-

ested in science as they are in literature, for instance.

Nevertheless, we believe that the old culture is moribund in the sense that its particular scale of values is undergoing revision. Science is becoming less an affair for specialists; it is acquiring a "human" value. An increasing number of people are beginning to realise that a great science, such as Physics, may offer objects for contemplation which are as delicate, as subtle, as exquisitely harmonious as the dreams of Plato—and much better founded. And in relation to man, his present state and possible future, science alone, to those who are not satisfied with less than verifiable knowledge, speaks with the accent of authority. The great constructions of science are grandiose without being chimerical; they are beautiful but not deceiving. Indeed, one sometimes has the feeling that it is only in science, nowadays, that one still meets with the spirit of adventure, the sense of boundless and glorious possibilities, with an exultant hope. Our poets and men of letters generally are extraordinarily tame and disillusioned creatures compared with our romantic and daring men of science. It is refreshing to turn from the lamentations of our literary men to such a book as the *Space, Time, Matter* of Hermann Weyl, if only for the fervour, the immense enthusiasm with which that highly accomplished mathematician writes. Einstein is his Columbus, with the difference that his America has indicated the existence of yet vaster

continents. And this enthusiasm is justified by its fruits ; it has inspired Herr Weyl to make what is unquestionably the greatest advance on Einstein's own work which has yet been made. It is not in Physics alone that we find this note. To the biologists, also, the world has become young again. Should our ignorant and unimaginative politicians, and our still more ignorant and unimaginative business men, succeed in turning the whole heroic effort and age-long struggle which has produced our present culture to a mockery, they will put an end to a curiously interesting and promising transition age, to an age which is at once *fin de siècle* and at the morning of a glorious renaissance. But if they do not succeed, if the ordinary man shows himself even a little worthy of the immense travail of his species, then we prophesy that science will become an integral part of the culture of the future. The new physics, the new biology, the new psychology, will be too obviously pertinent to all man's chief preoccupations for us to be able to pretend that the present narrowly conceived *humaniora* furnish a liberal education. We even believe that if the old arts are to become youthful again, it must be by a transfusion of blood. It will not be sufficient that the philosophy and literature of the future should "accommodate" themselves to the scientific outlook ; they must be inspired by it.

Meanwhile, scientific men must be charitable ; they must believe the best. If science is to become

an integral part of culture, scientific men must help to make this possible. We believe that much of the present interest in science is genuine; that it springs from a serious attempt on the part of many people to find out what science can tell them about themselves and the Universe they live in. Science is not hunted purely for its dividend-earning capacities or for its power of providing new thrills. Einstein, we understand, is suspicious of the popular interest his theory has evoked; "a mere fashion," he says. And doubtless his suspicion is largely justified. But we believe there is more in it than that—that there are many who, besides valuing the delightful dreams of the poets and philosophers, have an affection for *knowledge.* And when they find that the constructions of science are not one whit less delightful than the dreams of the poets, this affection may give rise to a permanent attachment. And with these new objects of interest will come a change in values. Men will learn to differentiate in their beliefs between those which are mere indulgences of emotion and those which correspond to objective truth. This is the path by which the mind becomes mature. It may not be, in all stages, a pleasant process, but it leads to increased freedom and increased power. The impossible will no longer be attempted, but the region of the possible will be seen to be vastly greater. Man will see in what directions he can shape his destiny, and he will be able to enter on the task with a rational hope. All his courage and

endurance will have a chance of victorious achievement; he will know that he is not engaged in a forlorn hope; the world will become young again.

THE RETURN OF MYSTERY

"It is a universal condition of the enjoyable that the mind must believe in the existence of a law and yet have a mystery to move about in."—JAMES CLERK MAXWELL.

That our thinking, and with it our feeling, is largely conditioned by assumptions which have no logical necessity, is a commonplace of philosophy, and is indeed apparent to the slightest introspection. Characteristic of any age is a body of beliefs, resting on more or less good evidence, and a group of feelings associated with those beliefs. The German language, so rich in indefinite but valuable general terms, afforded the word *Zeitgeist* for this complex, a word we have directly translated into the Spirit of the Age. The name is a good one; it indicates that we are dealing with something which is widely diffused and also subject to change. It is subject to change, but it pays a dominating rôle in the age to which it belongs. The Spirit of the Age is something that practically all the intellectual life of the age has in common. It is not manifested only in philosophical treatises or in

works of art; it is often manifested even more strikingly in statesmen's speeches and a country's domestic and foreign policy. It is a kind of intellectual and emotional atmosphere of which everybody is aware, but which probably nobody could define. We see, however, that a very important part of it consists of a sense of probability, of a tendency to accept certain kinds of explanation and to reject others.

For the last few decades, at any rate, Science has been the chief factor in forming this omnipresent sense of probability. As a matter of fact, it is probable that the influence of Science in forming the Spirit of the Age can be traced a very long way back, as far back as Copernicus. Not that we assert the existence of a close connection between the Science and the other intellectual activities of Copernicus's own age. The influence of which we speak is likely to manifest itself gradually; in particular, it may take a long time to affect the arts. And by the time it has percolated so far its origin may be forgotten; it may appear as a subconscious rather than as a conscious group of assumptions. By the time a scientific discovery becomes part of the mental furniture of an age, many of what were originally its possible implications will have become an integral part of it. The original discovery will then be merely the nucleus of a rich intellectual and, possibly, emotional complex, of which the parts are no longer envisaged separately. The work of Newton, for

example, and the great body of exact investigations he made possible, influenced the outlook of the nineteenth century chiefly in the direction of making determinism plausible. Such lecturers as Tyndall could confidently appeal to this mental predisposition on the part of their audience, although they had no need to postulate any direct acquaintance with the work of Newton and of his successors. The fact that Newton successfully formulated exact laws for the description of natural phenomena is the important aspect of his work from our present point of view. The influence of Copernicus was rather different. From the point of view of the history of Science his importance is that he made Newton possible; from our present point of view his importance is that he made Darwin possible. Copernicus' destruction of the isolated position of man's planet in the solar system prepares the mind for Darwin's destruction of the isolated position of man in the animal kingdom. They each shocked the same set of prepossessions.

The "materialistic philosophy" which was so marked a feature of the latter part of the nineteenth century, and which still forms, we believe, the prevalent intellectual complexion, owed the whole of its plausibility to its supposed scientific backing. Its basis was not merely biological; physics played quite as great a part as biology. The notion of determinism derived its strength, as we have said, chiefly from physics; biology was not in a position to demonstrate the exact correspondences required.

The ultimate grandiose vision of the purely natural and inevitable march of evolution from the atoms of the primitive nebula to the British Association for the Advancement of Science, as outlined by Tyndall in his Belfast Address, assumed the results of physics and astronomy as much as Darwin's *Origin of Species*. It was because biology was not the only science involved that it was possible to found a "materialistic" philosophy on Darwinism. One primary assumption of that philosophy, that life arises from "dead" matter, not only had no biological support, but had been decisively refuted by the experiments of Pasteur. But, as related to the general movement of Science, the hypothesis had the necessary plausibility. Considering the then existing evidence, this hypothesis, together with the hypothesis that mental states are produced by atomic movements in a strictly determinist manner, are, indeed, striking instances of the way in which the *Zeitgeist*, as much as the evidence, determines the direction of our thinking.

The importance of such conceptions cannot be over-estimated. Directly or indirectly they influence the whole life, if not of their time, then of an age which succeeds them. The philosophy in question had existed for centuries, of course; what made it influential was the scientific backing it received, for, in these matters, Science has for some time past played the dominant rôle. Neither religion nor philosophy has been able successfully

to oppose it; nowadays, indeed, they seem concerned only to agree with it. And if, here and there, a few artists have felt themselves outraged by what were supposed to be the teachings of Science, their influence has not been sufficient to deflect the stream. Such isolated protestants have had nothing but their feelings to oppose to what were considered to be facts, and the world, with what may have been a stupid honesty, has followed after the supposed facts. But the influence of Science on the arts would require a separate investigation. A certain stability is given to some serious art by its own tradition, and this may lessen its sensitiveness regarded merely as an indication of the spirit of its age. It is, nevertheless, very sensitive. In a history of modern literature, for example, it is impossible to exclude direct references to Darwin; it is usual, indeed, to devote some space to such "influences." And the artist who is not at home in his age may be reduced to impotence by it. Dostoevsky is a magnificent example of a writer who, extremely sensitive to the spirit of his age, and profoundly understanding it, strove to transcend it. A smaller Dostoevsky might well have been nothing. And is a post-Darwinian Beethoven, or a post-Darwinian Dante, really conceivable?

Now it is unfortunate that, so far as scientific discoveries form the Spirit of the Age, they do so at second-hand. The *Origin of Species* happens to be easy to read, but even so that body of thought

known as "Darwinism" owes its influence chiefly to such expositors as Huxley and Tyndall. The thing becomes set; it assumes hard, bold outlines; the issue has to be presented with something of the simplicity of an election cry. The universe of Science becomes finally a universe from which all mystery is banished and where the only ultimates are small, incompressible spheres whose movements and combinations produce—everything. The chasm separating this conclusion from the actual scientific evidence is not realised. Very tentative and almost fantastic hypotheses become dogmas, and it is as dogmas that they become influences. As a matter of fact the scientific evidence, even of Darwin's day, suggested quite other possibilities than those popularised as a "materialistic" philosophy. James Clerk Maxwell, who had a profounder insight into physical reality than any other man of his time, in a very little known essay, draws attention to the "singularities" characteristic of certain natural phenomena, and suggests that there are more singular points the higher the rank of the existence. "At these points, influences whose physical magnitude is too small to be taken account of by a finite being, may produce results of the greatest importance," and he warns his readers against "that prejudice in favour of determinism which seems to arise from assuming that the physical science of the future is a mere magnified image of that of the past."

Maxwell's remark is now seen to have been prophetic. The extraordinarily profound and far-reaching philosophical implications of the theory of relativity have hardly yet begun to be investigated, but we have already a general sense of their direction. Hermann Weyl's *Raum, Zeit, Materie,* for instance, the most thorough mathematical exposition of the whole theory which has yet appeared, hints not obscurely at the philosophical bearing of the new investigations. Now that, by Weyl's own work, Maxwell's electromagnetic equations are included by the theory, it seems to be scientifically complete. It presents us with a picture of the universe which is wholly unlike the picture of the early physics. In particular, an altogether different rôle is assigned to the human mind. So far as the exterior universe and the laws of nature are concerned, we see that the primary entity is the mind itself. It is the mind which has created, not only space and time, but the matter it has put within that framework. The mind has not created the universe out of nothing, it is true. But it is almost impossible to say anything intelligible in the old sense about the fundamental entities to which Einstein's theory leads us. Professor Eddington suggests that they may be " the very stuff of our consciousness," a somewhat mystical remark which nevertheless shows the trend of the new speculations. And, as a striking confirmation of Maxwell's view of the possible development of physical science, we may quote one of the last sentences of Weyl's profound

discussion: "It must be emphatically stated that the present state of physics lends no support whatever to the belief that there is a causality of physical nature which is founded on rigorously exact laws." Unfortunately not all men are mathematicians. The great and wonderful vista now opened up by Science—greater and more significant, we believe, than has existed at any previous time in the history of thought—is at present a consequence of highly abstruse investigations. The sheer technical difficulty of these inquiries will long hinder them from exerting their due influence on philosophy and, through philosophy, on the whole of the intellectual life of the age. But the new conceptions exist, and they derive their unshakable strength from the fact that they are the result of the severest Science. And surely no one can fail to see that they promise not only fascinating regions for thought, but a new liberation of the human spirit. Mystery, but more wonderful and full of promise than ever, has been restored to the universe.

MATHEMATICS AND MUSIC

It is possible that the old heading "Arts and Sciences" has been responsible for some of the barrenness which is so conspicuous a feature of æsthetic theory. For the heading seems usually to have suggested, not only that there is a difference between the arts and the sciences, but that the difference is of a fundamental kind. For the purposes of æsthetic theory the various arts are assumed to have more in common than any one of them has with any of the sciences. We find the writer on æsthetics expounding his principles in chapters headed Painting, Sculpture, Poetry, Music; but it is rare indeed to find the argument extended to mathematics and physics. Yet there is no evidence that such omissions are due to deliberate reflection; the philosopher has not decided, after examination, that the sciences are unæsthetic objects; we must assume that accidents of taste and education have prevented him from paying attention to what may conceivably be useful data for the formulation of a theory of æsthetic. Within the last two or

three generations scientific men have been thinking and writing a good deal about the philosophic basis and implications of their study, and it is significant that this inquiry has led many of them to insist on the æsthetic character of the satisfactions that science affords. The late Henri Poincaré, in particular, has shown that scientific theories are akin to works of art, and in this country, Dr. Norman Campbell has asserted his belief that great men of science are essentially great artists. The point of view is an interesting one, and suggests that fresh light may be thrown upon æsthetic problems by a new grouping of their subject-matter. Instead of putting the arts and the sciences on opposite sides of the fence, it may be helpful to see whether certain members of these two groups have not a natural affinity with one another, and so gain hints for a different and more comprehensive classification.

It is noteworthy, in this respect, that music has always occupied an exceptional position among the arts. Pater tried to relate it to other arts by saying it was the art to which all others aspire :

> The arts may be represented as continually struggling after the law or principle of music, to a condition which music alone completely realises ; and one of the chief functions of æsthetic criticism, dealing with the products of art, new or old, is to estimate the degree in which each of these products approaches, in this sense, to musical law.

MATHEMATICS AND MUSIC

It is characteristic of Pater's criticism, and of much of the criticism of his school, that it exists, as it were, within a world of its own. The meanings to be attached to his most important terms are always suggested or insinuated; they are never defined. The method is useful, perhaps even necessary, in dealing with a complex and elusive object, and where appeal is made to perceptions which lie on the fringe of consciousness. But it runs the grave danger of becoming altogether too tenuous to be intelligible when we make direct reference to the object it is supposed to illuminate. When, for instance, Pater says of the best music, "the end is not distinct from the means, the form from the matter, the subject from the expression," we become acutely aware of the absence of definition in each of these primary terms directly we think of any actual composition. We feel, indeed, that the terminology is not natural; in contemplating a poem the mind may be naturally impelled to distinguish between subject and expression as a kind of first effort in analysis; it is doubtful whether, in listening to music, this direction for analysis ever presents itself. So that to say that in music subject and expression are identical is not to say anything useful about music, but merely to declare that that kind of analysis is irrelevant. It is very probable that nothing is to be gained by first making distinctions which have a meaning for other arts and then bringing music into the scheme by saying

that for music such distinctions become meaningless.

But if we are to maintain that this kind of criticism is irrelevant, then music becomes not only an isolated art but the art of which we know least. If it cannot be accommodated as an example within the general body of æsthetic criticism, the criticism that uses such terms as Pater uses, then whatever general conclusions the multifarious writings of the last two centuries on the "beautiful" may be considered to have reached are not applicable to music. In this extremity it is natural, nowadays, to become "scientific." Comparative studies are undertaken: the music of Java is compared with the music of Bach: the evolution of musical devices is made clear; the psychological condition of the patient under music is examined: the time taken for the right degree of hypnosis to be induced is determined. That such methods may one day stumble upon important facts it would be rash to deny, but nothing has yet been reached which illuminates the particular problem that music presents. We are frankly of the opinion that, so far, the difficult utterances of certain mystical or semi-mystical writers throw more light on the real nature of music than do those of common sense.

Among such writers on music Schopenhauer is notorious; and it is worth while to dwell a little on his speculations, fantastic as they may

seem, since they contain an element common to all such interpretations, which does serve to isolate the essential problem of music. In Schopenhauer's æsthetic the object of all arts, except music, is to lead, by the description of objects, to the recognition of the Ideas (Platonic) whose appearance in multiplicity constitutes the world. All arts, therefore, have a transcendental function; their aim is to reveal to us the Platonic world of eternal essences or Ideas. But they have to raise us to this region *via* the objects of experience; in that sense they are also, therefore, concerned with the world of appearance and are dependent upon it. The case is different with music. Music is not concerned with the external world either as a symbol or as a reality. It is not even, in Schopenhauer's language, concerned with the Ideas, but refers directly to that "Will" which, in Schopenhauer's philosophy, underlies the Ideas themselves. The essence of his theory is given in the following passage:

> . . . so ist die Musik, da sie die Ideen übergeht. auch von der erscheinenden Welt ganz unabhängig, ignoriert sie schlechthin, könnte gewissermaassen, auch wenn die Welt gar nicht wäre, doch bestehen: was von den anderen Künsten sich nicht sagen lässt. Die Musik ist nämlich eine so unmittelbare Objektivation und Abbild des ganzen Willens, wie die Welt selbst es ist, ja wie die Ideen es sind, deren vervielfältigte Erscheinung die Welt der einzelnen Dinge ausmacht.

Or, as he says a little later on, the world may be regarded as embodied music.

It is not likely that anyone will take Schopenhauer's philosophy of music seriously; and even those who are sympathetic to his general view are not likely to find their sense of the ludicrous undisturbed by his identification of bass notes with the planets, tenor notes with the vegetable world, and so on. The intensity of his response to music and his humourless courage have led him to what are perhaps the most fantastic statements in all his writings. But what is worth noting is that so imaginative and fertile a speculator, because he was genuinely sensitive to music, had to give it a profoundly isolated position in his æsthetic. In so doing we think he recognised one very important difference between music and the other arts. It is true that music is independent of the world of experience in a way that other arts are not. It is true that there is a sense in which Schopenhauer is right when he says that music would exist even if the world did not. We can see what is meant if we compare the development of a "dramatic" piece of music, such as the first movement of Beethoven's C minor Symphony, with a great tragedy. The tragedy, as a condition of success, must make reference to our experience of life. The ostensible matter of the tragedy, the characters and incidents, must not violate our conception of reality if they are to be accepted. The tragedy must be plausible.

Such considerations obviously do not apply to music. It is meaningless to say that the development of a composition must satisfy our sense of probability. Yet there is a meaning in saying that its development seems either arbitrary or inevitable. The analogy that immediately presents itself is a chain of logical reasoning, as in the sustained development of a mathematical theorem. Such development is independent of all experience; the mind is obeying none but its own laws, and is paying no attention to any alien elements. And it is this characteristic of mathematics which seems responsible for the fascination the study possesses for its devotees.

> Remote from human passions, remote even from the pitiful facts of nature, the generations have gradually created an ordered cosmos, where pure thought can dwell as in its natural home, and where one, at least, of our nobler impulses can escape from the dreary exile of the actual world,

says Mr. Bertrand Russell in a typical passage. A strain of romantic eloquence seems, indeed, to be inseparable from the writings of mathematicians on their subject. But the analogy can be pressed more closely. There are elegant and inelegant mathematical demonstrations, those which merely "command assent," as Lord Rayleigh said, and those which provide a very high degree of æsthetic satisfaction. In these latter demonstrations the mind seems to be moving

with more swiftness and freedom; the whole demonstration seems to flower in a natural and spontaneous way; we have the impression of *inevitability.* Mathematical elegance, as Poincaré has put it, "n'est autre chose que la satisfaction due à je ne sais quelle adaptation entre la solution que l'on vient de découvrir et les besoins de notre esprit." It is as if there were a mode of living natural to the human spirit, an *unadapted* life, a life free from the necessity of accommodating itself to the elements, so largely alien, of the actual world. Mathematics is the expression of this life so far as the intellect is concerned. Is it too much to say that music is a fuller embodiment of this free life?

If we are to say this we must acknowledge that more than the intellect is capable of this free life, that there is a logic of the emotions as well as of the mind. This assumption is not difficult to make; indeed, if we reflect on our experience of some compositions, such as, to take the same example, the first movement of the C minor Symphony, it is difficult to avoid making it. And, in considering the matter from this point of view, we may gain some results useful for musical criticism in general. The theme of the movement in question is characteristic of many of Beethoven's themes in that it does not serve merely as a kind of structural skeleton on which a composition is to be built. In this respect

it differs from, for instance, many of Bach's themes. The theme immediately, in its ominous and arresting quality, throws the mind into a certain state of expectancy, a state where a large number of happenings, but only the happenings belonging to a certain class, can logically follow. As an analogous vague yet restricted initial preparation we may instance the entry of the witches at the beginning of *Macbeth*. As the music proceeds this rich, but more or less definite, state in the hearer becomes more and more precise, more and more subtle. It is, as it were, explored and shown in all its height and depth. What was pregnant in the theme is exhibited to us in all its extent, its definiteness, and its force. The theme was the entrance to a world. And we have the consciousness of logic, of *inevitability*, because at no point are we constrained. We exult because we are free; this is how we, too, would move but for our fetters, our alien, arbitrary fetters from which, for this time, we have been freed. And in none of this, unless we have incurably literary minds, are we ever reminded of experience. This life is no life that we have lived or that, on this planet, we could live. Music is as independent of the world as mathematics, but it cannot, like a system of geometry, even be applied to the real world as an hypothesis. It is even doubtful how far the emotions it expresses, when it is merely expressing emotion, correspond to those of real life. The sorrow of the bereaved father is

not the same thing as the sorrow of the bereaved lover, but music can express sorrow with thousands of *nuances*. It is customary to say that the emotions of music are generalised emotions; that its sorrow, for instance, is a kind of common denominator of all sorrows. But the exact opposite seems to be the case. The situations of real life, like the resources of language, are probably too limited to afford correspondences to the immense variety of emotions expressible in music. The musician is as free as the non-Euclidean geometer to create worlds which have no objective counterpart.

It is natural, therefore, in comparing the arts, that we should class mathematics and music together, since they resemble one another by their most intimate characteristics and differ, in these respects, from all other arts. It is worth noting, in this connection, that it is only in mathematics and music that we have the creative infant prodigy. Experience and learning, compared with what we vaguely call " instinct " or " gift," play a comparatively insignificant rôle; the boy mathematician or musician, unlike other artists, is not utilising a store of impressions, emotional or other, drawn from experience or learning; he is utilising inner resources so obviously independent of experience that, like Plato's slave, he seems to have brought them with him from some anterior life. And the artistic progress of a musician, if it be a true progress, means

primarily that he is making ever more accessible the riches of this inner life. It is difficult to avoid mysticism, or at least Platonism, at this point. But here again it seems to us that Schopenhauer understood something essential. When he says that music, like the Platonic ideas, is an embodiment of the "Will" that underlies all things, he does at least say that what is revealed to us by a composition is something other than the "personality" of the composer. The function of music is not, like that of literature, to illuminate this world, but there is a world it illuminates—a world at least as vast and independent of this one as that mathematical "cosmos" described by Mr. Bertrand Russell.

There is much music, of course, which suggests no such mystical fancies. With most of Wagner's music, for instance, there is no hint of other worlds, but rather a gorgeous colouring of this one—or of those aspects of this one which excite romantic poets with strong bodily appetites who can assume the background of the vigorous material prosperity of the nineteenth century. Such music is fully comparable with a certain kind of literature; all it lacks is the definiteness of statement, and hence the intellectual clarity, which the use of language affords. It may be even more powerful and subtle than literature can be—*Tristan und Isolde* expresses certain emotions with immense adequacy. But it is not doing something which

music alone can do; and, for that reason, it throws very little light on the peculiar problem of music. For the peculiar problem of music consists in its independence, in its power of transporting us to a world which is not otherwise revealed. To Schopenhauer, to whom both the world and music were embodiments of the same Will, there was a musical equivalent for every experience; and, it would seem to follow, for every musical utterance there is a corresponding experience. The two worlds are independent, but there exists between them, as a mathematician would say, a one-to-one correspondence. Yet he very strangely goes on to accept the theory that a musical utterance is a kind of generalisation of a number of distinct experiences. He points out that the musical setting of a poem, for instance, will serve for a number of similar poems. It is the "kernal" of all these poems which is given directly by the music. But it is equally true that the same poem will serve for several musical settings. When Beethoven, as one of sixty-three composers, composed his setting of Carpani's poem "In questa tomba oscura," he probably composed the best setting, since it is the only one that has survived; but among the other sixty-two there must have been many which, in Schopenhauer's phrase, were expressions of the "kernal" of the poem. The fact seems to be that, unless music is deliberately illustrative, it is not concerned with what is otherwise expressible. That is why

musicians are always dissatisfied with " literary " descriptions of music. However good in their own kind they may be, they are always felt to be irrelevant and even, in some way, a degradation of the actual musical utterance. It is felt that they exhibit a certain insensitiveness or lack of taste, as in that curiously popular image which likens twin hills to a woman's breasts.

As compared with literature, music is abstract. It is independent, as literature is not, of the facts of life. But just as there is some music which approaches to the condition of literature, so there is some literature which approaches to the condition of music. Such literature, while it is concerned with the world of experience, as literature must be, is concerned with that world as symbol and not as reality. Such literature, we might say, is not concerned to illuminate the world of what we here call experience, but to reveal something about the soul of man itself—or, if we prefer scientific jargon to mystical, to deal with the normally subconscious rather than with the normally conscious. Both kinds of literature have been called realistic, but they are realistic from entirely different points of view. Dostoevsky, for instance, regarded the realism of such writers as Zola as trivial. And can *Macbeth* be regarded as a realistic work, on the basis of the French conception of realism? *Macbeth* is, indeed, a striking example of the extent to which literature

can approach the condition of music. The whole apparatus of the play, the witches, the characters, the incidents, are so obviously not presented for their own sakes, but as symbols through which an overwhelming perception was to be conveyed. Here the fact that the literary artist must accommodate himself to the laws of the real world, that he must satisfy our sense of probability, seems hardly a hindrance. Our sense of probability is, indeed, purposely lulled by the entrance of the witches at the beginning. We are made aware that not the real world alone is concerned. In this respect the supernatural "machinery" of *Macbeth* performs an altogether different function from that in *Hamlet*. The whole of *Hamlet* is perfectly realistic in the tight sense. But the fact that literature must always use symbols differentiates it utterly from music. And just as we have seen that real life may present no analogies to what is revealed in music, so it may happen that the literary artist who has access to a wide and deep inner life may find no symbols, such as are essential to literary art, to convey his perceptions. Mr. T. S. Eliot has stated that *Hamlet* is an artistic failure because the whole play, considered as presentation in terms of symbols, does not adequately convey the emotions or perceptions we confusedly feel Shakespeare is trying to express. Whether or not Mr. Eliot is correct in his instance, his general thesis is perfectly sound. Even if *Hamlet* could be re-written

so as to satisfy Mr. Eliot, it is still true that there are some perceptions, states of mind, emotions, or whatever one likes to call them, which it is very difficult to believe are expressible in literature at all. Santayana gives a neat but somewhat trivial instance in one of his essays where he says that there is no human incident or group of incidents which can serve as a fitting symbol for pure radiant joy—a sort of prolonged, exultant, celestial state of joy. A shadow, to the mature mind, lies over the brightest and most delightful of life's happenings. He suggests that a poet who should try to imitate music in this respect could do little but write the word "Joy!" with exclamation marks. He could write nothing else that was unambiguous. And, indeed, a symbol is always ambiguous unless, like the symbols of the mathematician, its meaning is completely exhausted by its symbolic intent. The symbol distracts; it brings with it a crowd of irrelevant associations, and for that reason, even when the symbols are most superbly handled, as in *Macbeth*, the resultant communication is less definite than with music. But the very great, the immense, importance of literature lies in the fact that it can, partially at least, shape the facts of life so as to make them consonant with the nature of man. If experience can furnish symbols which express the deepest needs and aspirations of the soul, then life can be, at least partially, illuminated. For man can understand nothing which is not consonant with

his own nature. The literature which truly illuminates life is the literature which interprets life most fully in terms of our own emotions and aspirations. In this sense not only all literature, but all science, is anthropomorphic. Science is only possible in so far as it is logical. That is to say, the universe can only be understood in so far as its happenings are obedient to the laws of man's own mind. In its relation to mathematics, where the mind pays no attention to the arbitrary conditions of experience, physics plays something of the same part as is played by literature in its relation to music. Both physics and literature, in their universal function, are concerned with a world which *need* not obey the laws native to the spirit of man. Such illumination as they can give is dependent upon, as it were, what correspondences they can find. The revelation of life afforded by *The Brothers Karamazov*, for instance, consists in relating the phenomena of life to the deepest impulses of the spirit of man. Only so does life become in any measure truly comprehended; and it is in this respect that such works differ from those reports on life where we may recognise and assent to everything, but where our comprehension of anything is not deepened. Such works as *The Brothers Karamazov* may be called philosophic, if we use the word to include something other than purely intellectual understanding.

We have suggested that, if mathematics may be taken as the intellectual analogue of music, then it is not perhaps too far-fetched to say that such a science as physics may be taken as the intellectual analogue of literature, since both are concerned to interpret what we call the real in terms of what we call the ideal, while the two former arts are not concerned with the real. And the question arises whether the arts, mathematics, and music, which are not concerned to illuminate experience, are worthy of serious attention. In the case of mathematics the answer is not doubtful, since it has repeatedly shown itself applicable to real happenings, however little notions of utility may have played a part, or need have played a part, in its creation. Even the most remote mathematical theorems are not certainly immune from practical application. But no such claim can be made for music, and it is for that reason that to some philosophers music is a pleasing but essentially trivial art. To such philosophers music, while it may suggest spiritual profundities, is, after all, saying nothing of any possible significance. The adventures of the soul that it depicts are less significant even than a stage fight. Its one justification is the pleasure it affords ; it takes us out of ourselves in a way no other art can do, and after this refreshing interregnum we return to the things that matter. It may be so ; we can give no proof that it is not so ; we can only say we find the point of view

incredible. On this point, again, we certainly find the mystical view of Schopenhauer, if less intelligible, at least more convincing than that of common sense.

HUMAN TESTIMONY

Everybody normally acts on the assumption that the value of human testimony is an extremely variable quantity. The rules by which we assess the value of testimony, in the ordinary affairs of life, are of that thoroughly habitual kind that hardly involve conscious processes; they repose on two judgments, which we are always making. Our belief in direct testimony to an event is conditioned by the nature of the event and by our estimate of the "personal equation" of the witness. These two factors are not quite independent; it is very seldom, for instance, that we attribute "general untrustworthiness" to anybody who is known to us. Our experience usually teaches us that there are certain classes of statements—e.g. his breaks at billiards, the number of miles his motor-car runs on a gallon of petrol—for which that particular witness's credibility is at a minimum. For some other classes of statements we may have learnt to take his word without hesitation. What the mathematicians call the "credibility" of a witness is not, in the case

of any witness of whom we have personal knowledge, a constant figure. It varies with the event, often in an extremely complicated way. When Brown is listening to Jones talking about the enormities of Smith the extremely delicate and rapid weighing of probabilities being performed by Brown beggars any mathematical description. When the witness is personally unknown to us the matter becomes simpler. Our conclusions, one way or another, will be held with less confidence, but they will be more simply arrived at. We may, on the evidence supplied by the testimony itself—the tone of the letter, the man's manner in the dock—class the witness as a man of a certain type. Corresponding to each type we have a rough scale of credibility for different types of events. In cases where we know nothing of the witness beyond his bare statement that he witnessed the occurrence of the event our estimate of his credibility is based on very general and usually rather vague considerations. We are guided by two things: the initial credibility of the event and our estimate of the general value of human testimony. Both of these criteria, and in particular the second, are excessively ill-defined.

In the first place, what do we mean by the initial credibility of an event? There are very few cases where this notion can be precisely defined. The simple instances dealt with in the elements of mathematical probability do, it is true, permit of precise definition. The chance that a white ball

will be drawn from an urn containing five black balls and one white ball can be exactly estimated, for we are in possession of all the very simple relevant factors. But the probability that Romulus founded Rome obviously belongs to a very different category. And what is the initial credibility of a miracle? Hume, as is well known, thought that the *a priori* incredibility of a miracle was so great that its occurrence could not be established by human testimony. He is here trying to establish a ratio between the initial credibility of a class of events and the initial credibility of human testimony to such events. He is taking some kind of average in both cases, but it is difficult to see how such an average can be arrived at. Vague considerations of this kind are of no value in forming conclusions on matters of real interest to us, although they may be sufficient to warrant a lazy scepticism regarding what William James calls "dead hypotheses," or may form the basis for amusing and ingenious mathematical exercises. But we have no notion of an average initial credibility which is of any use in practice; each case must be judged on its own merits. And if, to take the second point, we reached some average for the value of human testimony in general, we should never, in practice, apply it. The utmost we can hope to do is to establish a more or less constant relation between the testimony of classes of witnesses and classes of events. We have to divide witnesses into

types, and for each given type estimate the value of its testimony to different classes of events. We must investigate the difference it makes when the witness is taken as isolated and when he is taken as a member of a group of witnesses. In this way we may hope to reach results which are of value in judicial procedure, in the study of history, and in various particular investigations, including those modern substitutes for miracles, the phenomena of spiritualism. We are, in fact, to investigate man in his capacity as a truth-recording instrument.

The result of such researches as have been made may be said, briefly, to show that human testimony has much less value than is normally assigned to it and, in particular, much less value than it is held to possess in a Court of Law. The experimental results obtained in this field are, indeed, often startling. It is hardly too much to say that one's first impulse, on becoming acquainted with the results hitherto reached, is to fall back on a general and dismayed scepticism regarding the value of human testimony to anything whatever. But a closer examination of the results show us that this attitude is unwarranted, and reinforces the common-sense assumption that the value of human testimony is a matter of degree, varying from complete worthlessness to a very fair presumption that the event occurred as stated. The investigation is useful chiefly in showing us what factors influence this value.

It is convenient to separate out these factors according to the scheme recently employed by Dr. Edmond Locard, in his analysis of police records over a number of years. The statements made by a witness repose, in the first place, on sensations which he has experienced. It might be thought too obvious to be worth mentioning that we require the witness who heard a sound, for instance, to have reasonably good hearing, and yet there are many cases where simple preliminary considerations of this kind are not taken into account. Professor Zöllner's famous book *Transcendental Physics*, for instance, alleged marvels that occurred in the presence of Slade, the medium; and these alleged marvels, of great influence in spreading a belief in spiritualism, were witnessed to by four professors, Zöllner, Fechner, Scheibner and Weber. But a member of the Seybert Commission, Mr. George S. Fullerton, as a result of personal interviews, found that two of these professors, Fechner and Scheibner, were partially blind at the time. Their sensations, therefore, in this respect, were untrustworthy. But defects of this kind may usually be determined and this factor conditioning the witnesses' credibility allowed for. Where a witness makes appeal to a sensation which may be checked the check should always be imposed. Thus Dr. Locard gives an instance where a witness stated that an event occurred in a mill at a certain hour. How did he know the hour? By hearing a clock strike at the time the

event occurred. A test was made, and it was found that the noise of the mill made the striking of the clock quite inaudible. The witness then remembered that he did not hear the clock strike until he had left the mill. Similarly, witnesses have testified that they saw a man leave a doorway, their post of observation being one from which the doorway could not be seen. Sensations may often be checked, however, and, to a careful inquirer, they need not be a grave source of error. But the next stage is concerned with the witness's perceptions. Of his sensations he will single some out for attention and neglect the rest. He singles out those which, for some reason or another, interest him most. It may quite easily happen, therefore, that the sensations most relevant to the inquiry in hand have been neglected. They have been filtered, as it were, through the medium of the witness's interest; and it is often the case that his interest has not been excited by the sensations most pertinent to the subsequent inquiry. It is on this fact that conjurers very largely depend for their success. The attention of the audience is distracted; they are invited to dismiss certain sensations as being of no importance, and, in general, it is remarkably easy to ensure this distraction of attention. Dr. Hodgson's case of the English officer and the Hindu juggler well illustrates this point:

Referring to the movements of the coins, he said that he had taken a coin from his own pocket and

placed it on the ground himself, yet that this coin had indulged in the same freaks as the other coins. His wife ventured to suggest that the juggler had taken the coin and placed it on the ground, but the officer was emphatic in repeating his statement, and appealed to me for confirmation. He was, however, mistaken. I had watched the transaction with special curiosity, as I knew what was necessary for the performance of the trick. The officer had apparently intended to place the coin upon the ground himself, but as he was doing so the juggler leant slightly forward, dexterously and in a most unobtrusive manner received the coin from the fingers of the officer, as the latter was stooping down, and laid it close to the others. If the juggler had not thus taken the coin, but had allowed the officer himself to place it on the ground, the trick, as actually performed, would have been frustrated.

Now I think it highly improbable that the movement of the juggler entirely escaped the perception of the officer; highly improbable, that is to say, that the officer was absolutely unaware of the juggler's action at the moment of its happening; but I suppose that, although an impression was made on his consciousness, it was so slight as to be speedily effaced by the officer's *imagination* of himself as stooping and placing the coin upon the ground.

We have here an instance of erroneous testimony by a witness to his own actions; testimony to the actions of other people is usually much less trustworthy. In this matter of direct perception we may discriminate still further. Tactile perceptions are of almost no value whatever. If a

witness be blindfolded and asked to determine, by touch alone, the nature, the volume and the material of an object, it will be found that the responses are very inaccurate. Experience of tactile sensations is relatively small and deductions therefrom are practically valueless. Thus the shock of a bullet entering the body may be interpreted as a slight blow, several dagger thrusts in the back as one thrust, and so on. A piece of ice drawn across the neck of a blindfolded man and warm water simultaneously poured on his chest have been stated to cause death by fright, the man having previously been informed that he was going to have his throat cut. Perceptions of odour or of taste are even less trustworthy; and here the difficulty of expression in precise terms, in the lack of a precise vocabulary, is complicated by the fact that the witness primarily perceives odours and tastes as pleasant or unpleasant, and pays attention only to that aspect of them. In cases of poisoning, therefore, evidence of this kind should be given very little value.

It is only when we come to the senses of hearing and of sight that we enter the region where perceptions may have evidential value. In the case of hearing, however, we must still proceed very warily. Experiment has shown that estimates of direction, for example, are quite valueless, since the different estimates made by different observers obey the laws of pure chance. Training can do a little, but very little, to render these perceptions

more trustworthy; in general, however, evidence as to the direction of a sound may be neglected. Estimates of the distance of a sound, also, are of very small value. The intensity of a heard sound depends on the intensity of the source, and also on its distance; and these two factors may be apportioned by the observer in the most arbitrary manner. In the case where the sound is articulate, as in overhearing a conversation, we are in the presence of still other sources of error, due to illegitimate inference and the association of ideas. For words which are not heard will be supplied by the witness in all good faith. He will have a theory of the purport of the conversation, and will arrange the sounds he heard to fit it. Edgar Allen Poe's example, in *The Murders in the Rue Morgue*, of the cries of an ape which were interpreted as remarks in different languages by different observers, is judged by Dr. Locard to be not at all fantastic. The same general source of error applies to visual perceptions. Not everything is observed, and the lacunæ are filled in by the witness in what seems to him the most probable manner. Oversights in proof-reading furnish a familiar example of this kind of error. But psychological experiments have produced much more striking examples. Claparède arranged for a man, wearing the mask of a clown, to enter his lecture room while a lecture was in progress. The students were afterwards asked to pick out this mask from a series of ten, and out of

twenty-three who attempted the task five only were successful—and even these successes were probably due, largely or wholly, to chance. The appreciation of distances, measured by the eye, is also very likely to be erroneous, the rule being that large distances are under-estimated and small ones over-estimated. A similar rule holds good of estimations of intervals of time. Errors of this kind are not pure errors of perception; they are due chiefly to lack of experience. A carpenter or builder would usually make a much more accurate estimate of the dimensions of, say, the side of a house than would the ordinary person; and astronomers who work with transit instruments have, as a class, very accurate perceptions of small intervals of time. It is chiefly lack of experience, also, which is responsible for the absurdly different estimates different observers will make of the number of people in a crowd. Dr. Locard states that, on questioning the policemen employed to keep order during a procession as to the number of people they estimated to be taking part in the procession, he obtained the figures five thousand, ten thousand, twenty-four thousand. The actual number, he states, was three thousand. And during another procession two middle-aged, intelligent, educated Paris journalists gave as their estimates for the number of people engaged, the one thirty thousand and the other three hundred thousand.

But now let us suppose that our witness, through

the medium of his imperfect senses and his partial attention, has received a certain image. What deformations may it suffer before it is produced as his evidence? If his memory of the incident has "lapsed" the image will undergo comparatively little alteration, but if it has often been called to mind it will probably suffer a very considerable change. Each time the image is recalled it will suggest others; the creative imagination gets to work, altering the emphasis, adding particulars, obliterating others, and the result will be as much a work of art as the reproduction of a fact. This tendency is particularly to be noticed with women, and with certain "excitable" types; it may be almost a national characteristic, as with Gascons and Sicilians. But all witnesses are prone to this kind of inaccuracy. Where the event has often been narrated by the witness the deformations become even more serious. For he is here exposed not only to the suggestions of his own creative imagination, but to the suggestions of other people. Every one wishes to make a success of the story he is telling, and the perception of what points to stress and what details to add is wonderfully ready and alert. It has often happened that a witness of perfect good faith has changed from the simple spectator of a drama to a prominent actor in it under the influence of repeated narration. Finally, we reach the point when the witness has to bear his formal testimony. His observations were imperfect, he

has imperfectly remembered them, his imagination has distorted them, and he is now to express them. A very considerable additional source of inaccuracy is likely to enter here. The witness probably cannot express his complete image—words may not be sufficiently precise to render the fine shades of his remembered perceptions. The nature of a sound, the kind of emotion expressed by a voice,—he may have no words for such things. And, in any case, the witness will not express his complete image. He will select—in accordance with his own estimate of what is pertinent and what trivial. He will do this even if he be allowed to talk to his heart's content ; but the method of question and answer as pursued in our Law Courts leads to even more imperfect expression. For he is forced to be precise where his recollection is vague, and he will either give a false precision to his answer or else profess complete ignorance. More often still the witness sins by exaggeration, and these exaggerations, in a thousand subtle ways, usually tend to add to his own importance. And it is important to notice that, besides tending to import fictitious details, the witness will tend to exaggerate his degree of conviction. Where he was originally doubtful he is now perfectly sure.

So far we have been considering the witness in isolation, and we have not considered the reaction upon his testimony of the emotional state produced in him by the event. Yet the

emotions accompanying the event have a great bearing upon the value of the witness's testimony. During the war it was noticed that the evidence of soldiers freshly wounded was often of the most fantastic description. They would testify to the details of castastrophes which had never occurred; they would assert that so-and-so had been decapitated in front of their eyes, and so-and-so buried by an explosion, when, as a matter of fact, nothing remotely resembling these events had taken place. And, under the influence of the comparatively slighter emotions of a spiritualistic séance, people will identify the same "materialised" mask as the features of their husbands, wives, sons, daughters. Under the influence of such emotions it may be taken as a general rule that perceptions deteriorate, and illegitimate inference, "unconscious reasoning," becomes more marked. Unconscious reasoning, indeed, plays a very great part in nearly all cases of mal-observation. It is well exemplified in the statement of the man sitting in a dark wood: "That dog's bark is not really a grasshopper, it is the squeaking of a cart." And Dr. Locard tells of one experiment he made, while in the Army, with a barometer which bore a remote resemblance to a clock. His suggestion that it was a clock was invariably accepted, even by the most eminent people, and several of them acquired their knowledge of the time of day from its indications, even when the hour so indicated was highly improbable. The testimony of great and com-

manding figures, even to the time of day, may therefore be open to suspicion. But the immense part played by unconscious reasoning is best seen in the psychology of conjuring, under which head it is fair to group the great majority of alleged spiritualistic phenomena. In this latter case we have further to recognise what Freud calls the "pleasure-pain principle," as distinguished from the "reality-principle." In other words, the witnesses are seldom disinterested; they strongly desire to witness certain events rather than others, and in such cases the slightest suggestion is sufficient to produce conviction.

When the witness is not isolated, but is a member of a group, the defects we have before noted, due to the creative imagination, are likely to be accentuated. The event will have been discussed and a uniform version gradually prepared. It is almost impossible, from the unanimous testimony of a number of witnesses who have been in consultation, to extract the original perceptions. The phenomenon of *mimétisme testimonial* makes its appearance, and may assume abnormal dimensions. A kind of collective hysteria may be induced, and there can be little doubt that some of the collective denunciations of witches which took place in the Middle Ages were manifestations of this form of mimicry.

Such are some of the results that have been reached by the modern investigations of the value of human testimony. They tell us little

we did not know before, for mankind has had an immense experience of human testimony; but they make our knowledge more precise and enable us to see what kinds of testimony are most open to suspicion. The effect of these researches on judicial procedure should be considerable, and their influence on the study of history not less marked. On this latter subject their influence can only be indirect, and in the direction, probably, of throwing still more doubt on the accuracy of historical records. The "credibility" of a witness still remains a vague quantity, but the chances are that it is something less than the value hitherto assigned to it. The investigation can claim no such precise results as those enunciated by Craig in 1699 in his *Theologiæ Christianæ Principia mathematica,* where, after proving that the suspicions of any history vary in the duplicate ratio of the times taken from the beginning of the history, he shows that faith in the Gospel, so far as it depended on oral tradition, expired about the year 880, and, so far as it depended on written tradition, would expire in the year 3150. The new investigations of the value of human testimony start from humbler, but surer, foundations.

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